Task Order No. 807
Contract No. PCE-I-00-96-00002-00

Report

INTERMEDIATE DRAINAGE REUSE IN BAHR BAGAR DRAIN BASIN
Main Document

Prepared By

Zhongping Zhu
Fakhary Khattab
Ibrahim Elassiouti
Ragab Abdel Azim
John Keith
Elsayed Mahdy
Robert Cardinalli
Samia Galal Saad
Mohammad Mohiedin

June 1999

For
United States Agency for International Development/Egypt

Environmental Policy and Institutional Strengthening Indefinite Quantity Contract (EPIQ)
Partners: *International Resources Group, Winrock International,*
and Harvard Institute for International Development

Subcontractors: *PADCO; Management Systems International; and Development Alternatives, Inc.*

Collaborating Institutions: *Center for Naval Analysis Corporation; Conservation International; KNB Engineering and Applied Sciences, Inc..; Keller-Bliesner Engineering; Resource Management International, Inc.; Tellus Institute; Urban Institute; and World Resources Institute.*

ACKNOWLEDGMENT

This report was prepared by the EPIQ Drainage Reuse Task Group. The Group included Dr. Zhongping Zhu (Task Leader), Dr. Ahmed Fakhry Khattab, Dr. Ibrahim Elassiouty, and Eng. Ragab Abdel Azim. Dr. Elsayed Mahdy and Dr. John Keith, the EPIQ Economic Task Group, Dr. Robert Cardinalli, EPIQ Social Task Group, and two local consultants, Dr. Samia Galal Saad, environmental specialist, and Dr. Mohamed Mohieldin, sociologist, also contributed several chapters to the report.

Eng. Hussein Elwan, the Head of Central Directorate for Water Distribution, initially proposed the intermediate drainage reuse, and his comments and suggestions during the benchmark implementation are highly appreciated.

The Sharkia and Salhia Irrigation Directorates and the Abou Hammad Irrigation District provided constant cooperation and support. In particular, Eng. Maher Elkhodary (Undersecretary of Irrigation of Sharkia), Eng. Mohamed Abdallah (Irrigation Inspector of Abou Hammad), *and* Eng. Sayed Mansour (District Engineer of Abou Hammad), are acknowledged for their enthusiasm and effort in implementing this benchmark.

The drainage monitoring teams from the General Directorate for Water Distribution in Lower Egypt (Tanta) and the Drainage Research Institute are acknowledged for their contributions.

Thanks are also extended to Dr. Shaden Abdel Gawad, Director of Drainage Research Institute, Dr. Fatma Abdel Rahman, Director of Groundwater Research Institute, and Dr. Mohamed H. Amer, Drainage Research Institute Advisor for their comments and constructive criticism of the report.

The EPIQ Water Policy Reform Program (WPRP) is a joint activity of the Ministry of the Public Works and Water Resources (MPWWR) and the US Agency for International Development (USAID). It is carried out under the auspices of the Agricultural Policy Reform Program (APRP). Program implementation is the responsibility of Winrock International, International Resources Group, and Nile Consultants.

Special thanks to Eng. Gamil Mahmoud, Chairman of the MPWWR project Steering Committee and the MPWWR Water Policy Advisory Unit, Dr. Craig Anderson, USAID Project Technical Officer, and Dr. Jeffrey Fredericks, EPIQ WPRP Team Leader, for their leadership and support.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

Agricultural drainage reuse is, and will continue to be, an important source of the irrigation in the Delta. However, the main drain reuse system is increasingly threatened by the contamination of municipal and industrial wastewater discharge and shows a stagnant or even a shrinking trend in operations. This calls for a policy change to shift the focus of drainage reuse from main drains to branch drains, i.e., to develop intermediate drainage reuse.

Benchmark C7 of the Agricultural Policy Reform Project states ***the GOE (MPWWR) will establish an intermediate drainage water reuse program for the Bahr Bagar Drain as a model for other areas.***

The verification indicator of Benchmark C7 is ***to establish an intermediate drainage reuse program, including operations plan and tender documents for needed pumps, for the Bahr Bagar drainage basin in at least one representative Irrigation District.***

Intermediate drainage reuse captures good quality drainage in branch drains, mitigates water shortage at branch canal tail ends, replaces unofficial use of drain water, and promotes farmers' participation and organization in irrigation management. One of the policy recommendations of the Water Policy Reform Steering Committee of the Ministry of Public Works and Water Resources at the Tranche II Concluding Workshop held in June 1998 was to develop intermediate drainage reuse in the Delta.

This document describes the efforts of the Ministry in implementing Benchmark C7.

Vision of Drainage Reuse in Bahr Bagar Basin

The Bahr Bagar drain is a contaminated main drain. It starts from the northeastern border of Greater Cairo, extends 180 km to the north, and ends at Lake Manzala on the northeast edge of the Delta.

In the south, the Qalubyia and Belbeise drains, which feed into Bahr Bagar, receive a large amount of urban sewage from the East Bank of Cairo. This has made Bahr Bagar more an open sewer than an agricultural drain. Since last October, Gabal El Asfar and Burka wastewater treatment plants have started cleaning the Belbeise drain, but the treatment of Shoubra El Kheima's industrial wastewater and the cleaning of the Qalubyia drain will take years. The Bahr Bagar main drain will remain contaminated for a while.

In the north, Bahr Bagar collects a mighty drainage flow from the newly reclaimed lands along the Salam Canal. The drain water is very saline, and reuse of the drainage is not yet envisioned.

The middle Bahr Bagar basin is a typical agricultural area. Many branch drains show low salinity (500-600 ppm) and good water quality indicators, and there is no concentrated industrial wastewater source in the area. Unfortunately, however, the area's drain waters all fall into Bahr Bagar and consequently lose their reusability. An important conservation strategy is to use these good drainage flows before they reach the main Bahr Bagar. Intermediate drainage reuse has good application potential in the middle Bahr Bagar basin.

Intermediate Reuse Program in Abou Hammad

Abou Hammad, an irrigation district in the middle Bahr Bagar basin, was selected as the pilot area for implementing Benchmark C7. Following careful analysis, seven drain locations (plus two existing pump stations) were identified as the potential drainage pumping sites.

Drainage Generations

To determine the availability of drainage for intermediate reuse pumping, understanding of the drainage generation is needed. A drainage-monitoring program was conducted in Abou Hammad from August 15 1998 to May 15 1999. The monitoring included weekly measurements of drain flows, daily observations of drain water levels, and three-time measurements of selected water quality parameters at selected drain locations.

A water balance approach was used to estimate the drainage generations. Two seasons (summer and winter) and two areas (northern and southern Abou Hammad) are distinguished in estimations. The summer season has different canal rotations, canal deliveries, irrigation crops, and unofficial reuse situations from the winter season. Southern Abou Hammad receives large amounts of canal leakage from the Ismalia Canal, and therefore presents a different mechanism of drainage generation from northern Abou Hammad.

Estimated drainage generations in the two seasons were compared to the monitoring values for the analysis of unofficial drainage reuse. It was found that, for northern Abou Hammad, the unofficial reuse was 5-7% of the area's canal inflow. Intermediate drainage reuse is desired to provide the proper pump capacity and operation schedule to replace a major part of this unofficial reuse.

Weir Construction and Night Storage

Small drains may not have adequate flows for continuous pumping. For effective drain water capture, drain weirs must be constructed downstream the pumping sites to store nighttime drain flows. Based upon the average drain depth in Abou Hammad, a weir height of 0.7-m was suggested. This height will allow drain flow to raise to a level at which field tile drainage outlets will not be blocked and maximum storage of nighttime drain water can be established.

One Day Before and After the Rotation

The operation of intermediate reuse stations must be consistent with canal rotations. To save part of the freshwater for filling canals at the beginning of the on-period and to extend the water delivery time for the users who missed the on-period, one day before and one day after the on-period are added to the intermediate reuse stations' operating time. In this way, intermediate reuse pumping will benefit farmers in both quantity and timing of irrigation supplies.

Based upon canal rotations in the two seasons, intermediate reuse stations will operate a maximum of 110 days in the summer and 90 days in the winter, for 200 working days a year. Two daily operation shifts are designed for reuse pumping. The morning shift will operate all installed pumps to maximize the capture of drainage stored during the nighttime, and the afternoon shift will use only one pump to handle the smaller regular drain flow.

Pump Capacities and Operating Hours

Three scenarios of pump capacity and unit selection were investigated. A desirable feature in pump station design is the continuous operation of pumping in each working shift. In many existing reuse stations, overly powerful pumps are equipped on small drains. Pumping operations have to be stopped every several hours due to low water levels. The result is long idle time and low efficiency. This problem should be avoided in the Abou Hammad intermediate reuse design.

Another factor in selecting pumps is the capacity of each branch canal to accommodate the pumped drainage. Most branch canals in Abou Hammad are narrow and shallow with capacities of 1 m^3 per second. A sudden reduction of irrigation demand along a branch canal may result in flooding in the small channel. Smaller unit capacity with flexible unit number would be more desirable.

Pump Station Design

The EPIQ drainage reuse task group prepared a detailed engineering design (including a project bidding document) of the seven potential pump stations in Abou Hammad. The achievable reuse in Abou Hammad is equivalent to 5% of the area's canal inflow. This figure can be a general estimate of intermediate drainage reuse. The rate is small compared to the main drain reuse, but is an additional part of reuse that the main drain reuse cannot harvest due to pollution.

Due to the fixed reuse locations, heavy pump operation duty, and expensive costs of mobile pumps, fixed pump facilities in permanent station houses are preferred. The total capital costs for constructing those pump stations will be about LE 1.16 million. The costs almost equal the costs of digging one groundwater well in the Farafa Oasis, although the lands the intermediately pumped drainage will irrigate are much larger than what the well water could cover. Intermediate drainage reuse is economically attractive compared to many other water conservation or augmentation options in Egypt.

Reduced Winter Canal Supplies

In the winter season, drainage pumping will be used to substitute canal supplies. This reduction will result in smaller production of drainage. The question is to what extent the canal supply can be reduced such that the intermediate reuse stations can continue operation at the reduced drainage generation. Careful analysis showed that a 10% reduction in canal supplies is acceptable, given the selected pump facilities.

Economic, Environmental, and Socio-economic Assessments

Economic viability of intermediate reuse is particularly sensitive to the size of the area served and the value input to the saved water. It appears that for canals with areas of less than 1,000 feddans, alternatives to fixed intermediate reuse should be considered. The farmer financial analysis suggested that farmers were generally unable to pay the full operation and maintenance (O&M) costs, and the government should be responsible for the major part of the capital and O&M costs of the intermediate reuse program. Only those farmers whose summer production is increased by using drainage water would be possibly willing to share part of the pump station O&M costs.

Environmentally, the dominant agricultural land use and the consequent good quality of drain water in Abou Hammad will sustain the intermediate drainage reuse in the area. The use of Abou Hammad's branch drain water is always better than the use of the contaminated Bahr Bagar main drain water.

In addition to structural, economic and environmental benefits, intermediate drainage reuse is favored by a majority of farmers surveyed. At present, farmers prefer government ownership and responsibility of pump facilities and operations. It is recommended that the GOE (MPWWR) pay all the costs, own the properties, and contract private companies to operate and maintain the intermediate reuse facilities until such time as there is a significant change in farmers' socio-economic status. The socio-economic assessment also demonstrated village women's role in drain water quality protection and the needs for including women as full partners in future drainage water management.

1. INTRODUCTION

1.1 Authorization

The Agricultural Policy Reform Program (APRP) is a four-year United States Agency for International Development (USAID) grant program involving several ministries. The Ministry of Public Works and Water Resources (MPWWR) is the primary Egyptian governmental agency charged with the management of water resources. MPWWR and USAID under the umbrella of the APRP jointly designed a water policy package, which consists of integrated water policy and institutional reforms. USAID supports the Ministry's efforts through annual cash transfers based on performance in achieving identified and agreed upon policy reform benchmarks and technical assistance.

Co-ordination among MPWWR, USAID and the water policy technical assistance program is through the Water Policy Advisory Unit (WPAU) and a project steering committee established by the MPWWR. Technical assistance for the water policy analysis activity is provided through a water resources results package task order (Contract PCE-I-00-96-00002-

00, Task Order 807) under the Environmental Policy and Institutional Strengthening Indefinite Quantity Contract (EPIQ) between USAID and a consortium headed by the International Resources Group (IRG) and Winrock International. Local technical assistance and administrative support for EPIQ is provided through a subcontract with Nile Consultants.

The EPIQ Water Policy team assists MPWWR to identify and carry out policy reform which will increase the global efficiency and productivity of Egypt's Nile water system under a water resources results package task order. EPIQ directly assists and takes a lead in identifying and achieving annual policy reform benchmarks, working closely with the MPWWR steering committee, WPAU, key ministry officials, and other APRP units.

This document describes the efforts and achievements made by MPWWR in the implementation of the intermediate drainage reuse benchmark.

1.2 Background

Benchmark C7 states that:

> ***GOE (MPWWR) will establish an intermediate drainage water reuse program for the Bahr Bagar Drain as a model for other areas.***

1.2.1 Why Intermediate Drainage Reuse?

Agricultural drainage reuse for irrigation is an important water conservation measure in the Nile Delta (*Abu Zeid, M., October 5-7, 1998*). There are two types of reuse practice in the Delta: official reuse and unofficial reuse. Official reuse is centralized pumping of drainage from main drains to main canals at large, government-operated mixing stations. Unofficial reuse occurs when individual farmers pump drainage water without government authorization.

Official drainage reuse emphasizes the centralized collection, transport and allocation of drainage resources and discourages local use of drainage resources. Centralized reuse has been expanded extensively in the past few decades, and is reaching the limit for further development. Since the 1990s, the contamination of drains from increasing wastewater discharge has threatened reuse pumping in many main drains. Several central reuse stations have been forced to stop operations because of unacceptable drainage quality, and 2-3 billion cubic meter (bcm) of reusable drainage water is lost to pollution every year in the Delta (*EPIQ Water Policy Team, June 1998*). In addition to the expensive wastewater treatment, the Ministry began looking at ways to avoid or reduce such losses. Unofficial drainage reuse has rapidly increased with the expansion in rice irrigation, and absorbed no less than 5 bcm of drainage water each year on the Delta plain. An increasing concern of the Ministry is how to better manage the unofficial drainage reuse.

Intermediate drainage reuse began in the 1990s as an answer to these questions. Intermediate reuse means mixing branch drain water for local reuse before the water goes to the main drain. Contrary to centralized reuse, intermediate reuse conserves drainage water at local level and helps mitigate water shortages at branch canal ends. Since intermediate reuse is an organized pumping action, it reduces the chance of unconscious use of contaminated water and encourages the involvement of farmers in water resources management.

Development of intermediate drainage use policy was recommended by the Water Policy Reform Steering Committee of the Ministry of Public Works and Water Resources at the Tranche II Concluding Workshop held in Hurgada on June 16-18, 1998.

1.2.2 Activities Conducted under Benchmark C7

The verification indicator of Benchmark C7 is

> ***To establish an intermediate drainage reuse program, including operations plan and tender documents for needed pumps, for the Bahr Bagar drainage basin in at least one representative Irrigation District.***

To fulfil the indicator, the following activities were carried out in the Tranche III period:

1. Selecting pilot district and identifying potential intermediate reuse sites. Through intensive field investigation and careful evaluation, Abou Hammad Irrigation District was chosen as the pilot area for intermediate drainage reuse development, and seven drain locations were identified as the potential reuse pumping sites. The selection was jointly made by the Irrigation Sector, Salhia and Shakhia Irrigation Directorates, and the EPIQ reuse task group.

2. Conducting drainage monitoring A drainage monitoring program was established to collect information on the water quantity and quality of the Abou Hammad District drains. Engineers from the Tanta General Directorate for Water Distribution measured

weekly drain flows and daily drain water levels at seven drain sites during August 1998 – May 1999. The Drainage Research Institute collected and analyzed drain water samples at ten selected sites in August 1998 and January and March 1999.

3. Assessing drainage reuse potential of Abou Hammad In cooperation with Salhia Directorate, Shakia Directorate, and Abou Hammad District, the EPIQ team conducted a water balance analysis for the Abou Hammad District, and assessed the reuse feasibility at each of the seven selected drain sites.

4. Designing pump stations and operating schedules The EPIQ team designed the needed pump stations, developed pump operating schedules, and provided project bidding document.

5. Organizing two social surveys The EPIQ team, in cooperation with Salhia Directorate and Shakhia Directorate, organized two focus group workshops to assess the reactions of farmers and local engineers to intermediate reuse. More than 40 farmers and 10 water engineers participated in the workshops and expressed their support for the new drainage reuse policy.

6. Conducting economic assessment An economic assessment of the proposed Abou Hammad intermediate reuse program was conducted to determine the new policy's economic benefit and financial feasibility.

7. Organizing environmental assessment The EPIQ reuse task group also carried out an environmental assessment of intermediate drainage reuse. The assessment reviewed a wide range of environmental and social issues.

8. Establishing a vision of pollution control and drainage management in the Bahr Bagar drain basin With the assistance of the Irrigation Sector, the EPIQ reuse task group studied pollution control and drainage management strategies in the Bahr Bagar drain basin and recommended targeting intermediate reuse development in the middle part of the basin.

Main actors in the benchmark implementation include:

- Salhia and Sharkia Irrigation Directorates and Agricultural Directorates – intermediate reuse development in the Bahr Bagar basin,
  - Abou Hammad Irrigation District and Agricultural Administration – pilot district for intermediate reuse development,
  - Water Distribution Directorate in Tanta – monitoring drain flows and levels, and

- Drainage Research Institute – monitoring drainage quality.

Cooperation was also provided by Cairo Wastewater Organization, National Organization for Potable Water and Sanitary Drainage, and Water Communication Unit of MPWWR.

1.3 Organization of the Report

Chapter 2 provides an overview of the Bahr Bagar drain basin and explains the need and possibility to promote intermediate drainage reuse in the middle part of the basin. The chapter also provides information on wastewater treatment in the areas east to the Nile in Cairo.

Chapter 3 presents seven potential drain locations for intermediate drainage pumping in Abou Hammad district, and reports on the drainage monitoring activities and results conducted in Abou Hammad during the Tranche III period. Using a water balance analysis, the chapter identifies the available drainage water for reuse in the northern and southern Abou Hammad areas during the summer and winter seasons.

Chapter 4 suggests several pump operation concepts for effectively capturing drain water, including drainage night storage, drain weir construction, two-season pumping, and one day before and after canal rotation. The chapter presents needed pump facilities and stations, designs pump operating schedules, and estimates pump station development costs. A tender document for construction of the pump stations is attached as Annex 1, Tender Document.

Chapter 5 is a summary of the economic evaluation of Abou Hammad intermediate drainage reuse development. Economic feasibility was determined for each potential pumping site using Benefit/Cost ratio, Net Present Value, and Internal Rate of Return. A farmer financial analysis was also carried out to explore farmer's willingness in reuse costs sharing. Details of the economic evaluation are included in Annex 2, Economic Assessment.

Chapter 6 is a summary of the environmental assessment of intermediate drainage reuse development in Abou Hammad. The assessment covers a broad range of environmental issues. An impact matrix is presented to demonstrate the various positive and negative effects of the drainage reuse plan. Suggested mitigation actions are summarized in the chapter. Details of the assessment are included in Annex 3, Environmental Assessment.

Chapter 7 presents a summarized socio-economic assessment of Abou Hammad intermediate drainage reuse. The assessment is based on two focus group workshops conducted in the field for collecting reactions of farmers and local engineers to intermediate drain reuse.

Socio-economic problems and issues related to drainage use, including women's role in drainage reuse, are discussed and analyzed. The assessment also addresses the sensitive but important issues of who will construct, operate, and maintain the intermediate reuse pump stations in the future. Details of the assessment are included in Annex 4, Socio-economic Assessment.

Conclusions are presented in Chapter 8. Literature referenced in the document can be found in Chapter 9.

2. OVERVIEW OF THE BAHR BAGAR DRAIN

The Bahr Bagar drain is a main drain in the East Delta. As shown in Figure 2-1, it starts from the northeastern border of Greater Cairo in two drains (Qalubyia and Belbeise) and extends 180 km to the north, ending at Lake Manzala on the northeast edge of the Delta.

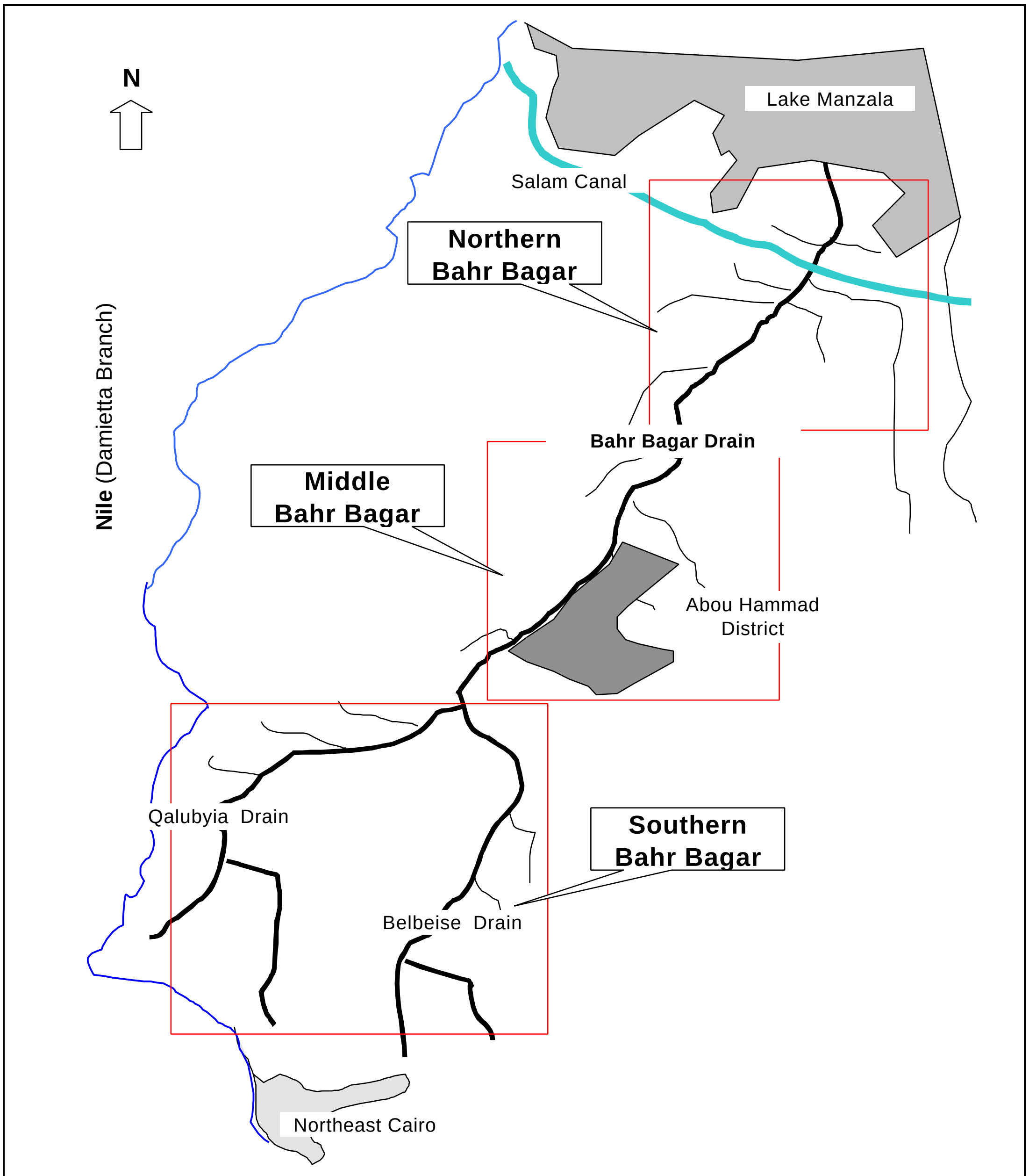


Figure 2-1: The Bahr Bagar Drain Basin

The Qalubyia and Belbeise drains receive large volumes of urban wastewater from the east bank of Cairo (the areas on east side of the Nile in Cairo). After the two drains' confluence, the Bahr Bagar main drain continues transporting the sewage to Lake Manzala. Bahr Bagar is severely contaminated, creating a negative environment and a big loss of usable agricultural drainage water in the basin. This chapter overviews the water pollution and its effects on agricultural drainage in the southern, northern and middle parts of the Bahr Bagar drain basin.

2.1 Southern Bahr Bagar and Cairo Wastewater

2.1.1 Qalubyia and Belbeise Drains

The east bank of Cairo, which has 6 million urban residents and numerous small industries, discharges its sewage, either treated or raw, to the Belbeise and Qalubyia drains. As seen in Figure 2-2, the average daily wastewater dumped in Belbeise and Qalubyia drains during 1996-97 reached 1.3 mcm and 0.5 mcm respectively. These discharges accounted for 59% and 50% of the two drains' flow rates (2.2 mcm and 1.0 mcm respectively) before the confluence point in Bahr Bagar. Qalubyia and Belbeise are more like open sewers than agricultural drains.

Table 2-1 presents selected water quality parameters measured along the Bahr Bagar (*Drainage Research Institute, December 1997*). All the measurements exceed the permits set in Law 48. Total californ bacteria counts, a pathogenic pollution indicator, were unbelievably high. The drain's full anaerobic conditions were clearly reflected in the low level of DO and high level of NH_4-N. In quality, the drain water was not much better than crude sewage. The Wadi reuse pump station stopped operations due to the bad drain water quality, resulting in a loss of 200 mcm of reuse per year in the Bahr Bagar drain basin. Without adequate treatment of the wastewater of Cairo's east bank, the southern Bahr Bagar drain cannot be cleaned.

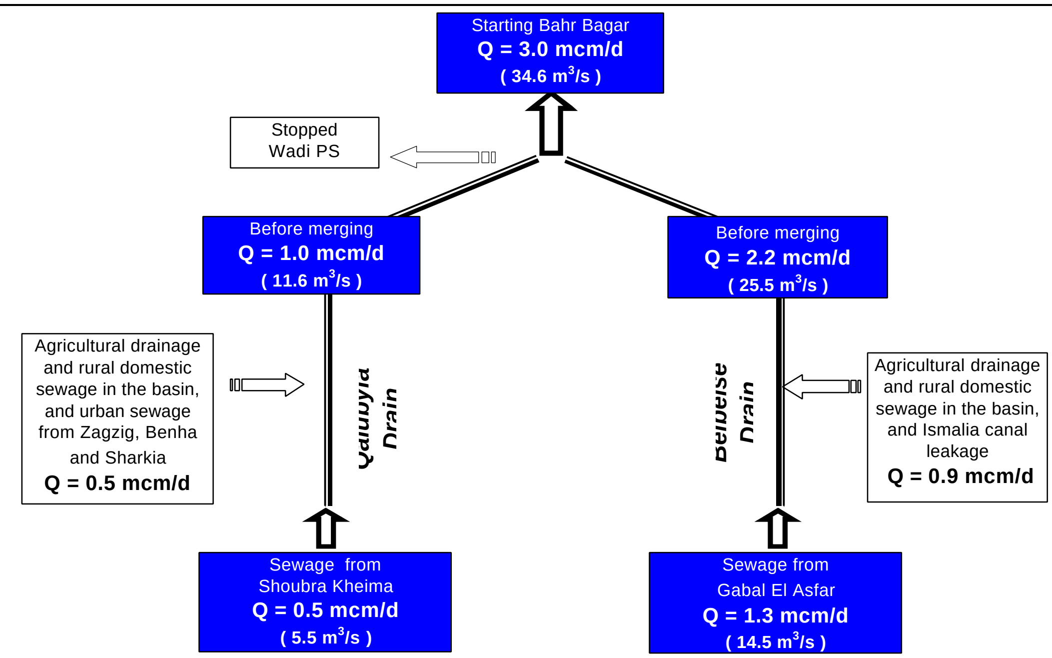


Figure 2-2: Wastewater Discharged to the Southern Bahr Bagar

Data source: Drainage Research Institute, December 1997

Table 2-1: Water Quality Parameters Execeding Law 48 Permits in Bahr Bagar Drain during 1996-97

	Belbeise *(beginning)*	***Qalubyia*** *(beginning)*	***Bahr Bagar*** *(beginning)*	***Law 48*** *Permits*
DO *(mg/l)*	*0.1*	*0.1*	*0.1*	*5*
TC *(MPN/100ml)*	*4.0E+08*	*1.0E+09*	*4.0E+08*	*5.0E+03*
BOD *(mg/l)*	*206*	*198*	*169*	*10*
COD *(mg/l)*	*388*	*386*	*336*	*15*
NH_4-N *(mg/l)*	*27*	*22*	*20*	*0.5*
P *(mg/l)*	*3.2*	*2.8*	*2.6*	*1*
Am-Detergents *(mg/l)*	*1.7*	*1.5*	*1.1*	*0.5*
Cd *(10^{-3} mg/l)*	*14.6*	*18.6*	*17*	*10*
Hg *(10^{-3} mg/l)*	*9*	*8*	*6*	*1*

Data Source: Drainage Research Institute, December 1997.

2.1.2 Wastewater of the East Bank of Cairo

Three sewage treatment plants - Shoubra Kheima, Gabal El Asfar, and Berka – serve the east bank of Cairo. The Shoubra Kheima plant currently operates at a primary treatment of 0.4 mcm/day. It discharges effluents to the Qalubyia drain through the Shebeen Kanatar branch drain. Qalubyia's water quality largely depends on the sewage of Shoubra Kheima City. The city has many small factories generating highly toxic wastewater, and the existing sewers and treatment capacity cover only 50-60% of the generated sewage. The large industrial components of the sewage threaten the success of the treatment. The cleanup of Qalubyia drain will take many more years.

The Gabal El Asfar plant started a secondary treatment capacity of 1 mcm/day in October 1998. It sends effluents to Belbeise drain through Gabal El Asfar drain. The Berka plant also has a secondary treatment of 0.35 mcm/day, and it diverts effluents to the Belbeise drain through Gabal EL Asfar drain. In total, these two plants produce a daily effluent of 1.35 mcm. Since the lands for using the effluent are not reclaimed yet, the clean effluents of the two plants are sent back to the Belbeise and mixed with Qalubyia's untreated sewage at the confluence point in Bahr Bagar. The expensive operations of Gabal El Asfar and Berka treatment plants are used for the dilution of pollution.

Table 2-2 presents future treatment capacities and effluent discharges planned by the Cairo Wastewater Organization and the General Organization for Sanitary Drainage. According to the plan, the secondary treatment capacity of the three plants will be doubled over the coming 20 years, and new lands will be reclaimed nearby to absorb 2.6 mcm of treated effluents per day (Figure 2-3).

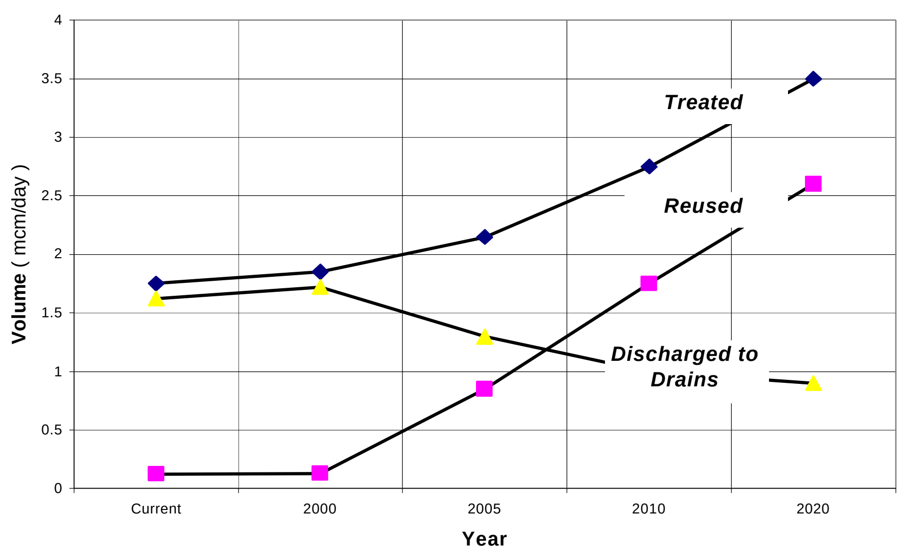
Table 2-2: Sewage Treatment and Reuse in Cairo's East Bank

		Current	2000	2005	2010	2020
Served Population	million	6.3	6.39	7.19	8.1	10.27
Treated Sewage	mcm/d	**1.75**	**1.85**	**2.15**	**2.75**	**3.50**
Primary						
Shoubra El Kheima plant		0.40	0.40	0.20	0.00	0.00
Secondary						
Shoubra El Kheima plant				0.20	0.40	0.40
Gabal El Asfar plant		1.00	1.00	1.30	1.80	2.50
Berka plant		0.35	0.45	0.45	0.55	0.60
Reused Effluent	mcm/d	**0.13**	**0.13**	**0.85**	**1.75**	**2.60**
from Shoubra El Kheima plant						
from Gabal El Asfar plant		0.13	0.13	0.85	1.35	2.20
from Berka plant					0.40	0.40
Discharged to Drains	mcm/d	**1.63**	**1.72**	**1.30**	**1.00**	**0.90**
to Qalubyia Drain		0.40	0.40	0.40	0.40	0.40
to Belbeise Drain		1.23	1.32	0.90	0.60	0.50

Data source: Zeinab, Nabih Monir, Janunary 1998.

The plan is very ambitious. Particularly questionable is the availability of large agricultural new lands in the northeast Cairo region for using the effluents. The land expansion plan in Gabal El Asfar was made in 1983, however, the urban expansion of Cairo in the past two decades has already extended beyond the planned area.

Figure 2-3: Planed Wastewater Treatment and Reuse in Region of East Bank of Cairo
(Data source: Zeinab Nabih Monir, Jan 1998)



Given the limited land space in Qalubyia Governorate, there is no new land for using the effluent of Shoubra Kheima treatment plant. The current level of effluent discharge of 1.6-1.7 mcm/day would likely continue in the Qalubyia and Belbeise drains for a while.

Besides the Cairo sewage discharges, there are also 0.5 mcm/day and 0.9 mcm/day of mixed sewage and drainage discharges along the Qalubyia and Belbeise respectively. They are not easily treated or reused. Therefore, the flow rate at the Bahr Bagar confluence point will likely remain at the current level of 3 mcm/day.

Drain water quality in Belbeise has been improved since the operation of Gabal El Asfar secondary treatment. However, substantial improvement of water quality in Qalubyia is not possible yet due to the slow and difficult pollution control in Shoubra Kheima (*Fatma El Gohary, December 1997*). Water quality in the Bahr Bagar main drain will depend on the cleanup of the Qalubyia drain.

The current reuse practice in the Delta is to blend drain water with canal water for general irrigation, without distinguishing crops to be irrigated by the water. Since treated sewage effluents cannot not be used for irrigating vegetables and certain crops, they should not, in principle, be brought into the general irrigation system. For this reason, the closed Wadi pump station, which used to divert Qalubyia drain water for general irrigation, should not be re-opened even if the Qalubyia drain finally receives treated effluents.

The reuse of treated effluents depends on the availability of land for suitable crops. This is always a constraining factor given the limited land space and agricultural development level in the Delta. The main benefit of wastewater treatment in the Delta is an improvement in the environment as opposed to an increase of general irrigation water. To avoid misunderstanding, the frequently used statement "reuse of sewage effluents for irrigation" needs to be better defined.

2.2 Northern Bahr Bagar

The northern Bahr Bagar includes a large area of new lands along the West Salam Canal. This area includes 208,000 feddans in the West Qantara, San Elhagar, Port Said, and Mataria irrigation districts. In addition, Bahr Bagar receives the North Ismalia drain coming from an area of 80,000 feddans along the Suez Canal. In total, the northern Bahr Bagar drains an area of 288,000 feddans. The area used to be part of Lake Manzala, and lands in the area are fertile but highly saline (*Elassiouti, I., 1995*). Two main drains, Bahr Hadus and Bahar Bagar, flow through the area. With its high topography, Bahr Hadus only drains a small portion of the new lands, while Bahr Bagar drains the majority.

The area has six large drainage pump stations. Table 2-3 gives the drain area, cultivation percentage, operation status, pumping rate, and salinity level at these stations. The national drainage-monitoring program does not cover these six stations. At present, an annual volume of 1.3 bcm of drainage is pumped out from the area. This volume is included in the published drainage yearbooks (*Drainage Research Institute, August 1995*). Since most lands are still in the "washing" stage without crop cultivation, current drainage rates are low at 1.3-4.7 mm/day, as shown in Table 2-3. They will increase in the future with increased irrigation in the area.

Table 2-3: Drainage Pump Stations in North Bahr Bagar

Drain Pump Stations	In District of	Total Area	Cultivated Area		Drainage		
					Pumped	Rate	Salinity
		(fed)	*(fed)*	*(%)*	*(bcm/y)*	*(mm/d)*	*(ppm)*
	Salam canal area	***208,000***					
1 Sahl Hossenia North PS[1]	*Mataria*	*30,000*	*14,000*	*47%*	*0.16*	*3.5*	
2 Sahl Hossenia South PS	*San Elhagar*	*64,000*	*40,000*	*63%*	*0.46*	*4.7*	*3,600*
3 Port Said South PS	*Port Said*	*46,000*	*5,000*	*11%*	*0.10*	*1.5*	*6,000*
4 Om El Rish PS	*West Qantara*	*21,000*	*1,000*	*5%*	*0.04*	*1.3*	
5 Sahl Port Said South PS	*West Qantara*	*47,000*	*1,000*	*2%*	*0.09*	*1.3*	
	Outside Salam	***80,000***					
6 North Ismalia Drain PS	*North Ismalia Drain*	*80,000*			*0.43*	*3.5*	*6-12,000*
	Total	***288,000***		*Currently*	***1.28***		

Note: 1) Data Source: Salam Canal Inspectorate

2) This PS is under construction

Drainage water in the northern Bahr Bagar is very saline, as seen in Table 2-3. This excludes the potential for one more recycle of the drainage in irrigation in the short term. Even in the long term, drainage salinity in the area will be difficult to decrease much, considering the fact that the supply source in Salam Canal is a recycled source.

2.3 Middle Bahr Bagar and Intermediate Drainage Reuse

The middle Bahr Bagar basin contains several agricultural irrigation districts: Abou Hammad (48,000 feddan) and Fakous (84,000 feddan) in the east bank, and Heseinia, West Fakous and Hehia (48,000 feddan) in the west bank. The total draining area in the middle Bahr Bagar basin is about 180,000 feddan.

The middle Bahr Bagar basin is a typical agricultural area. Soils are well washed from salts, and irrigation return flows have low salinity levels. There is no concentrated urban or industrial wastewater discharge in the region. Rural domestic wastes represent the major pollution source to agricultural drains. However, the basin's good quality irrigation drainage collects in the contaminated Bahr Bagar main drain, wasting their reuse values. An important drainage management strategy is to capture those irrigation return flows before they fall into the main Bahr Bagar. The intermediate reuse approach has great potential in the middle Bahr Bagar basin.

The region's irrigation supplies largely reply on the Ismalia Canal. The continuous expansion of rice irrigation has resulted in an increasing summer water shortage in the middle

Bahr Bagar basin and a heavier reliance on the Ismalia Canal. However, the Ismalia Canal is the most important freshwater source for the entire East Delta, and its allocation to agricultural irrigation in the middle Bahr Bagar basin is threatened by the growing water demands of other locations and other sectors. Intermediate drainage reuse development in the region will help ease the supply pressures on the Ismalia Canal and provide a valuable contribution to water allocations over the entire East Delta.

In summary, the drainage development potential in Bahr Bagar looks as follows: Bahr Bagar starts from the densely settled Cairo metropolitan in the south and ends in the highly saline new lands in the north. In the south, Cairo wastewater treatment should be continued for environmental improvement but not for an immediate benefit in general irrigation. In the north, drainage reuse potential is limited, at least in the present stage, due to the saline soil and high drainage salinity. In the middle, however, the typical agricultural area produces irrigation drainage of good quality and provides favorable conditions for intermediate drainage reuse development.

3. INTERMEDIATE DRAINAGE REUSE IN ABOU HAMMAD: *The Reuse Potential*

This chapter describes the selection of Abou Hammad Irrigation District as the focus of the intermediate drainage reuse development in Bahr Bagar drain basin, and the seven potential drain locations for intermediate reuse pumping. The chapter summarizes the results of drainage monitoring conducted since August 1998 for investigating the water quantity and quality at the seven potential pumping locations. The chapter also provides a water budget analysis for the Abou Hammad district, from which the area's total drainage generation and potential of intermediate reuse are estimated. These estimates are the basis for selecting reuse pump capacities and operating schedules in the next chapter.

3.1 Abou Hammad Irrigation District

Abou Hammad District is one of the irrigation districts in the middle Bahr Bagar drain basin. It has a cultivated area of 48,000 feddans served by the Saidia and East Wadi canals. The Bahr Bagar drain runs along the district to the west and drains the entire district by many branch drains. The district is a typical agriculture-based area without much industrial development or urbanization. Abou Hammad City is the only town area, and collection and trading of local agricultural products are the main activities. The area has mixed clay and sandy soils. Clay soil covers the oldlands between Saidia canal and Bahar Bagar drain, and sandy soil covers the newlands east to Saidia canal. Rice is the major summer crop in Abou Hammad, covering 35-40% of the total cultivation area. Clover and wheat are the major winter crops, taking 39% and 38% of the area respectively. More than half of Abou Hammad's lands experienced the Irrigation Improvement Project (IIP), many branch canal off-taking points are equipped with downstream flow control gates, and water user associations have been established in many villages (*Sir Mott MacDonald & Partners Ltd., May 1988*).

3.1.1 Canals and Canal Rotations

<u>Saidia and East Wadi are the two main canals serving Abou Hammad (Figure 3-1). Saidia canal runs 50 km from south to north, irrigating 26,000 feddans of Abou Hammad district and 52,000 feddans of Fakous district. East Wadi canal runs from west to east, serving 22,000 feddans in southern Abou Hammad and more lands on the west bank of Bahr Bagar drain.</u>

As shown in Table 3-1 below, the two main canals distribute irrigation water through many 3rd and 4th order branch canals. The 3rd-order canals have an average length of 5-km and bed width of 2-m. The 4th order canals have an average length of 2-km and bed width of 1-m. The lowest-order canals are the mesqas operated by farmers. Each mesqa serves an average area of 60 feddans (and 40-50 farmers). The average land holding in Abou Hammad is about three feddans.

Table 3-1: Canal System in Abou Hammad District

canal name	Canal Order	Area (fed)	Length (km)	Width (m)
Saidia	**2**	**26,000**	**27.8**	**14.6**
Qenry	3	10,000	19.4	4.8
Om Hagar	3	5,661	11.1	2.3
Homma Elkheil	4	700	3.7	1.3
Faraa Om Hagar	4	1,760	2.8	1.5
Waslet Om hagar	4	500	0.8	1.5
Elganayen	3	1,350	2.3	1.2
Faraa Elsaidia	3	200	0.4	1.0
East Wadi	**2**	**22,000**	**11.5**	**14.0**
Elsouda	3	1,000	4.1	1.5
Elshoon	3	500	3.0	1.3
Elset oioun	3	800	4.1	1.3
Shenbara	3	1,230	4.7	1.5
Elzallag	3	1,470	3.4	1.8
Elmashaa	3	544	3.0	1.0
Abou Eldekoun	3	1,700	3.6	1.4
Waslet Abou Eldekoun	4	150	0.6	1.0
Shaker	3	600	2.5	1.0
Elfaras	3	1,000	4.9	1.0
Elsheikh Hamed	3	4,000	2.3	3.0
Elsherkia	4	880	2.8	1.3
Elkhareg	3	1,000	3.3	1.0
Elamoud	3	500	2.5	1.0
Mit Radini	3	1,200	6.5	1.5
Waslet mit Radini	4	200	1.7	2.0

Data source: Abou Hammad Irrigation District

Abou Hammad has two irrigation seasons. The summer season starts in May and ends in September, and the winter season starts in October and ends in April of the following year. Accordingly, canal water supplies in Abou Hammad are delivered on a seasonal rotation basis. As will be revealed in the next chapter, canal rotations affect the dates and duration of intermediate reuse pump operations.

In the winter season, there are three rotations, each with a 15-day interval. Canals are divided into three groups, each with 5-day on-period and 10-day off-period. In the summer season, there is a difference between the rice and non-rice areas. For the rice areas, two rotations with a 10-day interval each are used. The on-period lasts 4 days and the off-period lasts 6 days. For the non-rice areas, the same three rotations as the winter season are used. Therefore, in summer season, canals are divided into five groups. Groups 1, 2 and 3 are operated on three rotations, and groups 4 and 5, on two rotations. However, since the entire district is a rice area, canals in Abou Hammad in the summer only operate on two rotations.

3.1.2 Drains and Drainage Reuse

Average salinity concentration in branch drains in Abou Hammad is 500 ppm or less. Farmers use drain water even without mixing it with canal water. Village domestic sewage transports mainly organic pollutants to the drains and has not caused serious contamination of the drain water quality, as will be discussed in detail in a later section. Currently the sewage of Abou Hammad City discharges into Elazzazi drain. However, the city has a wastewater treatment plant under construction, and the moderate volume of the sewage effluent does not have a significant effect on the water quality of Elazzazi drain. In general, branch drain water quality is adequately good for irrigation. Title drainage systems are fully constructed in the cultivated lands of Abou Hammad. All drainage water falls into Bahr Bagar by branch drains. Table 3-2 below gives each drain's characteristics.

Table 3-2: Drains in Abou Hammad

Drain	***Length*** *(km)*	***Serving Area*** *(fed)*
Southern Part		
Upper Blad Elayed	*17.0*	*5,900*
Seneika	*3.7*	*1,000*
Elmasid	*7.7*	*7,800*
Elsoda	*3.1*	*1,100*
Elawkaf	*4.1*	*2,800*
Kafr Ayoub	*2.1*	*1,000*
Rageh	*4.3*	*3,400*
Oliem	*3.1*	*2,000*
Northern Part		
Elazzazi	*11.2*	*10,800*
Lower Blad Elayed	*4.8*	*5,800*
Elharami	*7.5*	*12,400*
Elkhattara	*5.8*	*4,000*
Elqorein	*5.0*	*3,000*
Toweher	*8.6*	*1,900*
Bani Gray	*3.2*	*1,600*

Data source: Abou Hammad Irrigation District

The mechanism of flow generation in drains in the southern part of the district differs significantly from that in the northern part of the district. The area north to East Wadi canal is referred to as the *Northern Area* in this report. In this area, return flows from irrigation fields compose the majority of the drain water. Downward drainage infiltration dominates the vertical interaction between drain water and groundwater aquifers. The area has 40,000 feddans of lands drained by two large branch drains, Elazzazi and Elharami.

The 8,000 feddans south to East Wadi canal is referred as the *Southern Area*. This area's high aquifer water table caused by the canal seepage along Ismalia Canal drives a big upward flux to the drains. Drain flows are generated more by the upward groundwater flux than the irrigation return flows. According to the 1993/94 drainage yearbook (*Drainage Research Institute, August 1995*), average drainage rates are as high as 5 mm/day compared to that of 1.5 mm/day in the Northern Area. Upper Blad Elayed drain, which originates from another irrigation district in the south, is the large branch drain in the Southern Area.

Abou Hammad has a centralized drainage mixing station on Upper Blad Elayed drain. It pumps drainage into the East Wadi canal, which serves the *Southern Area* of Abou Hammad and other districts on the west bank of Bahr Bagar. The station is equipped with three units of pumps (each with capacity of 3.5 m^3/s), operates 24 hours a day and lifts 0.5 mcm of drain water per day. The narrow drain channel of Upper Blad Elayed is always over-filled by the upward seepage water of Ismalia Canal. The intermediate reuse development on the drain will help reduce the pressures on the centralized pumping station.

Unofficial reuse actively happens in rice season in Abou Hammad. In the case of Omm Elhagar canal and its associated drain of Elharami, at least 10% of the canal command area (about 500 feddans in 9-10 mesqas) faces canal supply shortage problems and farmers must pump drainage water in the summer season. Assuming that about half of the area's farmers have their own pumps, there may be 4-5 pumps operating in the area (one pump per mesqa). A farmer's pump usually has capacity of 5-6 horsepower and lifts 0.02 m^3/s of water. Accordingly, the area would have an unofficial use of 0.08-0.10 m^3/s, or even more. This suggests an average unofficial reuse rate of 2^{-5} $m^3/s/fed$ (or 1.73 $m^3/day/fed$) in Abou Hammad.

There are two existing branch drain pump stations in Abou Hammad. One is at the end of Elazzazi drain (3 units of 0.15 m^3/s), and the other is at the end of Elharami drain (2 units of 0.15 m^3/s). They both pump drainage into the Om Hagar canal and are functioning as intermediate reuse stations. However, they were constructed in 1992 for developing continuous canal flow in Om Hagar during the IIP time. Due to improper design and management, these two stations are not operating at the desired efficiency, as will be discussed in the next chapter.

3.1.3 Why Abou Hammad?

The selection of Abou Hammad as the pilot area for intermediate reuse in Bahr Bagar drain basin was jointly made by the Irrigation Sector, Sharkia Directorate, Abou Hammad District, and the EPIQ reuse task group. The rationale for the selection included the following:

- Abou Hammad is a typical agricultural area without major industrial development. The good quality water in various branch drains is wasted in the polluted Bahr Bagar main drain.
- The prevailing occurrence of water shortages at canal tail ends and unofficial drainage reuse in Abou Hammad provide a case where the intermediate reuse approach could find best application.
- Field visits and initial analysis indicated good potential for reusing branch drain water and reducing canal freshwater supplies.
- Officials and irrigation engineers in Sharkhia and Shalhia directorates are more willing and interested in intermediate drainage reuse development.
- Abou Hammad has good experience in IIP and water user association development, an important factor in the success of intermediate reuse operations.

3.1.4 Potential Pumping Locations

Seven drain locations (plus two existing drainage pump stations constructed by IIP project) were identified as the potential reuse pumping sites, as shown in Table 3-3. The locations satisfy the following criteria:

- Adequate drain flow in summer season,
- Good quality drain water,
- No nearby industrial pollution source,
- Short canal supply in summer season,
- Adequate canal capacity to accommodate drain water,
- No drinking water service in the canal, and
- Short distances between the pair of canal and drain.

Table 3-3: Potential Locations for Intermediate Reuse Pumping

No.	Canals		Drains	
	Name	Location	Name	Loaction
	Northern Area			
1	Abou Eldekoun	km 5.20 (end)	Lower Blad Elayed drain	km 1.5
2	Elmashaa	km 2.79 (end)	Elazzazi Ext. drain	km 2.0
3	Elsherkia	km 2.79 (end)	Elazzazi drain	km 7.0
4	Om Hagar branch	km 2.83 (end)	Elharami drain	km 7.0
5	Hemma Elkheil	km 3.65 (end)	Elharami branch drain	km 3.0
6	Waslet Mit Radini	km 1.0	Toweher drain	km 2.0
(existing)	Om Hagar	km 5	Elazzazi-end	end
(existing)	Om Hagar	end	Elharami-km-1.35	km 1.35
	Southern Area			
7	Shenbara	km 3.0	Elmasid drain	km 1.0

Figure 3-2 shows the geographic position of the seven potential pump stations and the two existing pump stations in Abou Hammad district.

3.2 Drainage Monitoring in Abou Hammad

Intermediate reuse involves branch drains or even lower-order drains. The existing drainage monitoring programs conducted by the Drainage Research Institute do not cover these smaller drains. To investigate the drainage availability and suitability for intermediate reuse, a drainage-monitoring program was conducted in Abou Hammad from August 15 1998 to May 15 1999. The program included weekly measurements of drain flows, daily observations of drain water levels, and three-time measurements of selected water quality parameters at selected drain locations.

3.2.1 Weekly Drainage Flows

Drain flows were measured once a week at six drain locations, four of which are potential pumping sites (Elmasid drain, Lower Blad Elayed drain, Elharami branch drain, and Toweher drain). The other two are the end points of Elazzazi drain and Elhrami drain, as shown in Figure 3-3. Due to the thick cover of water hyacinth in the drain channels, the drain flows of Elazzazi-km-7 and Elazzazi-km-2 were not measured.

Table 3-4 gives the drain flow measurements from August 19 1998 to April 15 1999. The average drainage outflows were 2.62 m^3/s in the summer and 2.81 m^3/s in the winter from the Northern Area, and 2.85 m^3/s in the summer and 1.85 m^3/s in the winter from the Southern Area. Note that the volumes of seasonal totals in Table 3-4 are calculated based on 150 days of summer season and 210 days of winter season.

1998 was an abnormally wet year along the Nile. Several billion cubic meters of High Aswan release passed through the Nile irrigation system in the second part of the year, when the monitoring program was conducted. To some extent, the 1998 measurements in Abou Hammad exaggerate the normal flows passing through those drains. The monitoring figures should be cautiously discounted.

3.2.2 Daily Drain Water Levels

Drain water levels at the seven proposed reuse locations were recorded daily in the monitoring period. With the level records and data of drain channel sections, flow depth and slopes can be determined. Average water depths of 0.43 m, 0.20 m, 0.23 m and 0.30 were calculated for Elmasid, Lower Blad Elayed, Elharami branch and Elazzazi drains. Drain water depths were used to determine pump suction depth and the needs for downstream weir construction. In Elmasid drain, for example, the water depth was 0.43 m and the drain bed depth was 1.0 m. To effectively withdraw the water in the drain, a downstream weir must be constructed.

3.2.3 Drainage Quality Monitoring

Water quality in Abou Hammad's branch drains was monitored by the Drainage Research Institute on August 23 1998 and December 26 1998, and on March 22 1999. Drain water samples were taken at ten selected drain sites, including the seven potential reuse sites, two existing reuse pump station sites, and one site on the Bahr Bagar main drain. The three monitoring dates covered the typical months of the summer and winter seasons.

The monitored water quality parameters include BOD, COD, MPN, PH, TDS, and adj SAR. Table 3-5 summarizes the lab analysis results of those parameters. Clearly, the branch drains have better water quality than the Bahr Bagar main drain. MPN in most of the branch drains did not exceed a level of 1 million cells / 100 ml, compared to that of 2.4-11 million cells / 100 ml in Bahr Bagar main drain. The site of Elazzazi-km-2 had higher BOD and COD measurements than other branch drains. Its MPN level reached 2.4 million cells / 100 ml in one of the three measurements. This is due to the disposal of Abou Hammad City's wastewater in the drain. Environmentally, the site is not preferable as an intermediate reuse pumping location.

The COD/BOD ratios were low at all locations. This is an indicator of low industrial pollution components in the drain water. Salinity levels in the branch drains were low at 400-600 ppm, the equivalent level of the canal freshwater in the Delta. Such drainage water can be used in irrigation without mixing. Salt concentration, therefore, is not a constraint in Abou Hammad's intermediate drainage reuse development.

3.3 Water Balance Analysis

The purpose of analyzing the water balance of Abou Hammad is to investigate the drainage generation in the area and determine the potentially reusable volume of drain water through intermediate reuse pumping.

Canal Inflows

As mentioned above, the Abou Hammad district receives its quota of irrigation supply from two canals, the East Wadi and the Saidia canals. However, both these canals serve more districts than Abou Hammad, and only a portion of their flows at intakes on Ismalia Canal are attributed to Abou Hammad. In addition, the East Wadi canal is joined by drainage flow pumped from the Blad Elayed central reuse pump station on its way to the west. Table 3-6 below presents the manipulated canal inflows to the two areas in Abou Hammad based upon the 1997-98 data.

Table 3-6: 1997-98 Monthly Canal Inflows to Abou Hammad *(mcm)*

Seasons	East Wadi Canal				Saidia Canal		Canal Inflow to	Canal Inflow to
	Canal Intake	Canal Exit	Blad Elayed PS	To Abou Hammad	Canal Intake	To Abou Hammad	**Northern Area**	**Southern Area**
Winter								
1997 Oct	12.4	16.7	9.1	4.8	25.3	9.1	12.0	1.8
Nov	16.8	16.4	9.3	9.7	31.9	11.4	17.5	3.7
Dec	11.9	16.7	8.9	4.2	35.9	12.9	15.5	1.6
1998 Jan	14.8	16.8	3.2	1.2	26.3	9.4	10.2	0.5
Feb	16.0	15.3	9.2	9.9	30.4	10.9	17.0	3.7
Mar	26.4	17.6	10.2	19.1	40.4	14.5	26.3	7.2
Apr	24.1	16.8	10.7	17.9	49.5	17.7	28.9	6.8
sum	122.5	116.3	60.6	66.8	239.8	85.9	**127.4**	**25.3**
Summer								
1998 May	24.9	17.4	11.0	18.5	51.1	18.3	29.8	7.0
Jun	33.7	17.5	12.0	28.2	70.7	25.3	42.8	10.7
Jul	36.9	18.2	17.0	35.7	65.3	23.4	45.6	13.5
Aug	29.4	18.3	16.8	28.0	62.6	22.4	39.8	10.6
Sep	18.5	17.1	13.6	15.0	30.2	10.8	20.1	5.7
sum	143.3	88.4	70.4	125.3	279.8	100.2	**178.1**	**47.4**
Yearly	265.7	204.7	131.0	192.1	519.6	186.1	**305.5**	**72.7**

Data source: Abou Hammad Irrigation District

The Abou Hammad portion of the East Wadi canal equals to the East Wadi intake flow minus exit flow plus the Blad Elayed reuse pumping. The Abou Hammad portion of the Saidia canal is proportional to its land area in the total land area served by the canal. The inflow to the Northern Area is calculated as the Abou Hammad portion from Saidia canal plus its land area based proportion from the Abou Hammad portion from East Wadi flow. The inflow to the Southern Area is proportional to its land area in the total area served by East Wadi in Abou Hammad. As seen in Table 3-6, summer season canal flows are 178 mcm to the *Northern Area* and 47 mcm to the *Southern Area.* Winter season canal flows are 127 mcm to the *Northern Area* and 25 mcm to the *Southern Area.* The average daily canal delivery is 1.19 mcm in the *Northern Area* and 0.31 mcm in the *Southern Area* in the summer, and 0.60 mcm in the *Northern Area* and 0.12 mcm in the *Southern Area* in the winter.

According to Table 3-6, the per-feddan water supply in 1997-98 in Abou Hammad was 7,650 $m^{3,}$ a higher figure than the average water allocation of 6,500 m^3 per-feddan in the Delta region (*Zhu Z, Laila Abed, and Nagy G. Yakoub, August 1995*). This must be attributed to the large rice area in Abou Hammad. The ratio of the summer and winter canal supplies din 1997-98 was about 1.4, which is consistent with the general ratio in the Delta.

Crop Consumptive Use

Crop consumptive water uses, as shown in Table 3-7, were estimated based upon the cropping patterns provided by the district engineer and agricultural extension service. The crop evapotranspiration figures are the standard values used by the Irrigation Sector in Nile water allocations (*Sir Mott MacDonald & Partners Ltd., 1991*).

Table 3-7: Crop Water Consumptions in Northern Abou Hammad

		With assumed 35% of Rice		
Seasons	*Crops*	*% of Area*	*ET (m3/fed)*	*ET (mcm)*
Summer	*Rice*	*35%*	*4691*	*66*
	Maize	*35%*	*2430*	*34*
	Cotton	*6%*	*2818*	*7*
	Vegetables	*15%*	*1411*	*8*
	Gardens	*9%*	*2811*	*10*
	Sum	*100%*		***125***
Winter	*Wheat*	*38%*	*1609*	*24*
	Beans	*11%*	*1281*	*6*
	Berseem	*39%*	*2265*	*35*
	Vegetables	*5%*	*1361*	*3*
	Gardens	*7%*	*1207*	*3*
	Sum	*100%*		***72***
			***Annual ET** (mcm)*	***197***

Abou Hammad is not officially allowed to cultivate rice. In practice, however, the district had 14,000 feddans (or 35% of the total area) planted in rice in 1997-98, according to the district engineer and agricultural extension staff. The Egyptian Survey Authority also reported that 37% of Abou Hammad's lands were planted in rice in 1997 and 1998. Similar analysis was conducted for the *Southern Area*.

Other Evaporative Depletions

Other evaporation means the water depleted from evaporation of canal and drain surface areas and phreatophyte, and water lost in domestic uses. An annual 1.1-m of free surface evaporation (0.7-m in the summer and 0.4-m in the winter) was assumed in the calculation. Data of the lengths and widths of the canals and drains in Abou Hammad were provided by local engineers and officials. An average width of 6 meters of phreatophytes on each side of canal and drain was assumed. Table 3-8 below gives the estimated results.

Table 3-8: Other Evaporative Depletions

		Northern Area	***Southern Area***	***Northern Area** (mcm)*		***Southern Area** (mcm)*	
				Summer (evp. 0.7 m)	*Winter (evp. 0.4 m)*	*Summer (evp. 0.7 m)*	*Winter (evp. 0.4 m)*
Canals							
Length	*Km*	*101*	*19*				
Surface area	*1,000 m^2*	*725*	*28*	*0.51*	*0.29*	*0.02*	*0.01*
Pheatophytes area	*1,000 m^2*	*1212*	*233*	*0.85*	*0.48*	*0.16*	*0.09*
		Sum	*Sum*	*1.36*	*0.77*	*0.18*	*0.10*
Drains							
Length	*Km*	*44*	*9*				
Surface area	*1,000 m^2*	*571*	*43*	*0.40*	*0.21*	*0.03*	*0.02*
Pheatophytes area	*1,000 m^2*	*529*	*103*	*0.37*	*0.23*	*0.07*	*0.04*

3.3.1 Drainage Generation in *Northern Abou Hammad*

It is assumed that, on a seasonal basis, no water surplus or deficit would be built at the end of a season within the area's boundary, and the area's canal inflow is fully balanced by crop ET, other evaporative depletion, and drainage generated over the area. Table 3-9 below gives the *Northern Area*'s summer and winter water balances. As seen in the table, the estimated drainage generation in the Northern Area is about 50 mcm in the summer and 54 mcm in the winter. The average drainage rate for the two seasons is about 2.0 mm/day, which is consistent with the estimate of the Drainage Research Institute.

For the winter season, the estimated drainage of 54 mcm matches the monitored figure of 51 mcm, since the small difference of 2.6 mcm may include groundwater interaction or other errors in estimation or monitoring. For the summer season, however, the monitored drainage of 34 mcm is much smaller than the estimated figure of 50 mcm. The difference could represent the area's unofficial drainage pumping in the rice season. Subtracting the winter monitored-estimated difference of 2.60 mcm from the summer monitored-estimated difference of 15.82 mcm, we obtain an amount of 13.2 mcm as the estimate of the area's summer unofficial reuse. This amount is about 7% of the total canal inflow. The intermediate reuse design is desired to provide the proper pump capacities and operation schedules to replace a major part of this unofficial reuse.

Table 3-9: Northern Area Seasonal Water Balances

	Summer Season [1]		***Winter Season***	
	mcm	*m^3/s*	*mcm*	*m^3/s*
Inflow				
Canal water (1997-98 records)	*178.00*	*13.73*	*127.37*	*7.02*
Groundwater [2]	*0.00*	*0.00*	*0.00*	*0.00*
Evaporative Depletions				
Crop ET	*125.05*		*71.52*	
Other Depletions	*3.13*		*2.21*	
Drainage Generation				
Estimated	*49.82*	*3.84*	*53.64*	*2.96*
Monitored in 1998-99	*34.00*	*2.62*	*51.04*	*2.81*
Implied Unofficial Reuse	*15.82*	*1.22*	*2.60*	*-*
Drainage Rate (mm/d)	*1.98*		*2.13*	
Outflow / Inflow (%)	*28%*		*42%*	

Notes: 1) Based upon the 35% rice cropping case
2) Groundwater wells were basically not operated during 1997-98.

The balance calculation is based on an assumption of 35% rice cultivation. With a larger rice cultivation percentage, a smaller drainage estimate and consequently a smaller unofficial reuse estimate will result from the water balance calculation. An estimate 5-7% ratio of unofficial reuse over canal inflow in northern Abou Hammad looks reasonable.

3.3.2 Drainage Generation in *Southern Abou Hammad*

Table 3-10 below presents the *Southern Area*'s seasonal water balances.

Table 3-10: Southern Area Seasonal Water Balances

	Summer Season [1]		***Winter Season***	
	mcm	*m^3/s*	*mcm*	*m^3/s*
Inflow				
Canal water (1997-98 records)	*47.40*	*3.66*	*25.60*	*1.41*
Groundwater [2]	*0.00*	*0.00*	*0.00*	*0.00*
Evaporative Depletions				
Crop ET	*25.01*		*14.30*	
Other Depletions	*0.29*		*0.17*	
Drainage Generation				
Estimated	*22.10*	*1.71*	*11.13*	*0.61*
Monitored in 1998-99	*36.97*	*2.85*	*33.51*	*1.85*
Concluded Ismalia Canal Seepage	*14.87*	*1.15*	*22.39*	*1.23*

Note 1: Groundwater wells were basically not operated during 1997-98.

Leakage along the Ismalia Canal and its impact on the area's drainage generation is critical. As seen in the table, the estimated drain water is 22.10 mcm in the summer and 11.13 mcm in the winter, while the measured drain flow was 39.97 mcm and 33.51 mcm respectively in the two seasons.

There is little unofficial drainage pumping in the winter. The differences between estimated and measured should come mostly from the water leakage of Ismalia Canal. As seen in the table, the estimated seepage flows were 1.15 m^3/s and 1.23 m^3/s respectively in the two seasons. They are well consistent with the estimates made in earlier research investigations (*Elwan, Hussein S., February 1987*). The *Southern Area* has many scattered swamps. The Elawkaf pump station lifts the swamp water to Elmasid drain, which merges as Blad Elayed drain in Abou Hammad. The pump station is equipped with three units of pumps (two of 0.5 m^3/s, and one of 1.0 m^3/s). The station operates day and night in the summer to move the excess water in the drain. Intermediate reuse development will help reduce the pressures on that pump station.

4. INTERMEDIATE DRAINAGE REUSE IN ABOU HAMMAD: The *Operations Plan and Bidding Document*

In this chapter, the drain flows to be pumped at each of the seven drain sites in different seasons are calculated. Low weir construction in drains is suggested to establish drain water storage in the nighttime and durable pumping in the daytime in the shallow drain channels. Pump equipment and station layout and civil work are designed. The operating hours of each reuse pump station are planned based upon the drain flows to be captured in different seasons and the rotations of irrigation supplies in different branch canals.

The chapter also analyzes the expected cut in canal freshwater supply in Abou Hammad after the intermediate drainage reuse development. Engineering costs of pump equipment and pump station construction for the Abou Hammad intermediate reuse are provided. Ownership and staffing requirements of these pump stations are also discussed.

4.1 Available Drain Water

4.1.1 Drain Water at Each Location

Given the estimated total drainage generation in the *Northern* and *Southern Areas*, the available drain flow at each of the nine locations is calculated proportionate to the total drain area. Table 4-1 gives each location's draining area, related physical parameters, and the available drain flows estimated in different seasons.

The estimated available flows in Table 4-1 are not much different from the drainage monitoring measurements (Table 3-4), except particular locations in particular seasons. Some locations were not accessed in the monitoring due to weed over-growth in the drain beds, and the monitoring was incomplete for a year period when this report was produced. 1998 was an abnormal flooding year in the Nile, and the filed measurements may have exaggerated the drain flows. Therefore, the water balance estimates were used as the base for designing pump capacities and operating hours in the Abou Hammad intermediate reuse development.

Table 4-1: Each Location's Draining Area, Other Parameters, and Available Drainage Flows

	Name	Draining Area (fed)	Total Length (km)	Section Width (m)	Water Depth (m)	Upstream Distance (km)	Estimated Drain Flow Summer (m3/s)	Estimated Drain Flow Winter (m3/s)
Northern Area								
1	*Lower Blad Elayed*	1,660	4.5	15	0.37	2.9	0.35	0.12
2	*Elazzazi-km-2*	900	11.2	8	0.44	2.0	0.09	0.07
3	*Elazzazi-km-7*	6,732	11.2	15	0.44	9.2	0.65	0.50
4	*Elharami-km-7*	1,653	7.5	18	0.35	2.3	0.16	0.12
5	*Elharami Branch*	1,900	6.8	11	0.32	5.2	0.18	0.14
6	*Toweher*	2,260	8.6	10	0.49	7.0	0.22	0.17
7 (existing)	*Elazzazi-end*	10,800	11.2	15	0.44		1.23	0.80
8 (existing)	*Elharami-km-1.35*	12,400	7.5	18	0.35		1.19	0.92
	Sum	38,305					4.07	2.83
Southern Area								
9	*Elmasid*	10,800	7.7	13	1.03		2.85	2.35

4.1.2 Weir Construction and Night Storage

The experience of Abou Hammad's two existing reuse pump stations shows that very often there is not adequate drain flow in the shallow branch drains for full-time pumping in the daytime, and nighttime irrigation is not yet accepted by the farmers. Pumps are frequently idle in the daytime, and the nighttime drain flows are wasted. To sustain daytime pumping, the storage of nighttime drainage flow is key. This can be achieved by constructing overflowing weirs downstream the pump stations (Figure 4-1). Based upon the average drain depth in Abou Hammad, a height of 0.70 meter was selected for drain weirs. This height allows the increase in drain flow to a level at which field tile drainage outlets will not be blocked. Pump capacities and operating hours will be determined by the nighttime storage behind the weir plus the regular drain flow.

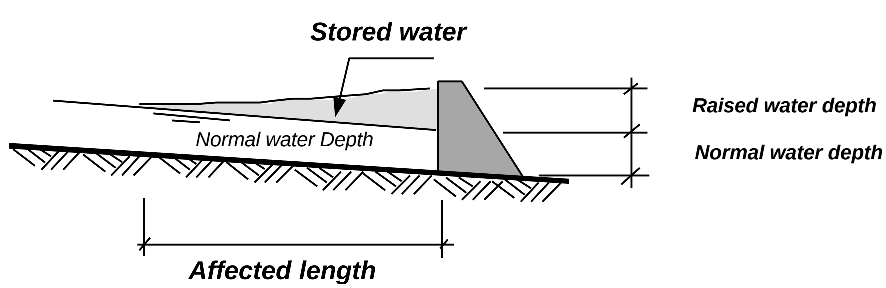


Figure 4-1: Nighttime Flow Storage in Drains

Table 4-2 gives each potential pumping location's raised water level, length of backward water surface (or the "affected length"), and volume of water stored behind the weir during the nighttime. The nighttime is defined as an 8-hour period. There is no need to construct a weir for the Elmasid drain, as this drain always experiences adequate flow.

Table 4-2: Nighttime Stored Water behind the Weirs *(at a standardized weir height 0.7 m)*

Proposed Pump Stations	*Name*	*Raised Levels*		*Affected Lengths*		*Stored Water*	
		Summer (m)	*Winter (m)*	*Summer (km)*	*Winter (km)*	*Summer (m^3)*	*Winter (m^3)*
Northern Area							
1	*Lower Blad Elayed*	*0.33*	*0.24*	*2.94*	*2.43*	*7,369*	*4,417*
2	*Elazzazi-km-2*	*0.26*	*0.24*	*2.00*	*2.00*	*2,054*	*1,957*
3	*Elazzazi-km-7*	*0.26*	*0.26*	*2.57*	*2.57*	*4,945*	*4,945*
4	*Elharami-km-7*	*0.25*	*0.22*	*2.30*	*2.22*	*5,223*	*4,399*
5	*Elharami Branch*	*0.35*	*0.30*	*3.46*	*3.03*	*6,586*	*5,055*
6	*Toweher*	*0.21*	*0.21*	*2.11*	*2.11*	*2,230*	*2,230*

4.2 Pump Operating Schedules

4.2.1 One Day Before and After the Rotation

Canal water deliveries in Abou Hammad are provided on a rotation basis. In the winter season, there are three rotations, and the canals are divided into three groups. Each group of canals has five days with water (on period) and ten days without water (off period). In the Irrigation Sector's water allocation scheme, they are called rotation 1, rotation 2, and rotation 3. In the summer season, there are two rotations, and canals are divided into two groups. Each group has four days with water (on period) and four days without water (off period). These two rotations are called rotation 4 and rotation 5.

The operations of intermediate reuse must be consistent with the canal rotations. To save part of the freshwater for filling canal channels at the beginning of the on-period and extend the water delivery time for the users who have missed the on-period, the intermediate reuse stations' operating time should be extended by one day before and one day after the on-period.

In this way, intermediate reuse pumping will benefit farmers in both quantity and timing of irrigation supplies. As earlier defined, the summer season is a five-month period that includes about 19 turns (150 days / 8 days per turn = 18.8 turns) of rotation. Therefore, there will be about 113 days (18.8 turns * 6 days per turn = 113 days) for intermediate reuse stations to operate. For the seven-month period of winter (including the 15-day canal closure period), the operating time will be about 91 days (195 / 15 * 7). The intermediate reuse stations will operate 110 days in the summer and 90 days in the winter, for a maximum of 200 working days per year. With these pump-operating figures, the total amount of drain water to be pumped by the intermediate reuse in Abou Hammad can be calculated.

4.2.2 Three Operating Scenarios

The intermediate reuse stations will have two operating shifts each day. The morning shift will go from 6 a.m. to 2 p.m., while the afternoon shift will be between 2 – 10 p.m. In the morning shift, pump stations, except the one at Elazzazi-km-2, will all operate with two units for adequately capturing the water stored in the nighttime. In the afternoon shift, all stations will operate with one unit to catch the regular drain flows.

According to the estimated drainage volume at each potential site, pump capacities should be in the range of 0.1 – 0.15 m^3/s, depending on the number of units to be used. To make the best use of pump capacity, the following three scenarios of capacities and units were examined, as shown in Tables 4-3, 4-4, and 4.5.

<u>*Scenario #1*</u> *One unit of 0.15 m^3/s at Elazzazi-km-2 and two units of 0.15 m^3/s at the other six sites,*

<u>*Scenario #2*</u> *One unit of 0.10 m^3/s at Elazzazi-km-2, two units of 0.15 m^3/s at Elmasid, Lower Blad Elayed, and Elazzazi-km-7, and two units of 0.10 m^3/s at the other three locations, and*

<u>*Scenario #3*</u> *One unit of 0.10 m^3/s at Elazzazi-km-2, two units of 0.15 m3/ at Elmasid, and two units of 0.10 m^3/s at the other five sites.*

A desirable feature in pump design is the ability for continuous operation of pumping in each working shift. In many existing reuse pump stations, overly-powerful pumps are equipped on small drains, pumping operations have to be stopped every few hours due to dropped drain water levels. The result is long idle time and low efficiency. These should be avoided in the Abou Hammad intermediate reuse design.

Table 4-3: Scenario 1

	Name	Unit Capacity	Summer					Winter				
			Morning		Afternoon		Pumped	Morning		Afternoon		Pumped
		m^3/s	units	hrs	units	hrs	1000 m^3/d	units	hrs	units	hrs	1000 m^3/d
Northern Area												
1	Lower Blad Elayed	0.15	2	8	1	8	13.0	2	7	1	7	11.3
2	Elazzazi-km-2	0.15	1	8	1	5	6.8	1	7	1	4	5.9
3	Elazzazi-km-7	0.15	2	8	1	8	13.0	2	8	1	8	13.0
4	Elharami-km-7	0.15	2	8	1	8	13.0	2	7	1	7	11.3
5	Elharami Branch	0.15	2	8	1	8	13.0	2	8	1	8	13.0
6	Toweher	0.15	2	8	1	8	13.0	2	5	1	8	9.7
7 (existing)	Elazzazi-end	0.15	2	8	1	8	13.0	2	8	1	8	13.0
8 (existing)	Elharami-km-1.35	0.15	2	8	1	8	13.0	2	8	1	8	13.0
						sum	97.5				sum	90.2
Southern Area												
9	Elmasid	0.15	2	8	2	8	17.3	2	8	2	8	17.3
						sum	17.3				sum	17.3

Note 1: With an assumption of 100 and 90 operating days in summer and winter seasons respectively.

Table 4-4: Scenario 2

	Name	Unit Capacity	Summer					Winter				
			Morning		Afternoon		Pumped	Morning		Afternoon		Pumped
		m^3/s	units	hrs	units	hrs	1000 m^3/d	units	hrs	units	hrs	1000 m^3/d
Northern Area												
1	Lower Blad Elayed	0.15	2	8	1	8	13.0	2	7	1	7	11.3
2	Elazzazi-km-2	0.10	1	8	1	7	5.4	1	8	1	5	4.7
3	Elazzazi-km-7	0.15	2	8	1	8	13.0	2	8	1	8	13.0
4	Elharami-km-7	0.10	2	8	1	8	8.6	2	8	1	8	8.6
5	Elharami Branch	0.10	2	8	1	8	8.6	2	8	1	8	8.6
6	Toweher	0.10	2	8	1	8	8.6	2	8	1	8	8.6
7 (existing)	Elazzazi-end	0.15	2	8	1	8	13.0	2	8	1	8	13.0
8 (existing)	Elharami-km-1.35	0.15	2	8	1	8	13.0	2	8	1	8	13.0
						sum	83.1				sum	80.8
Southern Area												
9	Elmasid	0.15	2	8	2	8	17.3	2	8	2	8	17.3
						sum	17.3				sum	17.3

Note 1: With an assumption of 100 and 90 operating days in summer and winter seasons respectively.

Table 4-5: Scenario 3

	Name	Unit Capacity	Summer					Winter				
			Morning		Afternoon		Pumped	Morning		Afternoon		Pumped
		m^3/s	units	hrs	units	hrs	1000 m^3/d	units	hrs	units	hrs	1000 m^3/d
Northern Area												
1	Lower Blad Elayed	0.10	2	8	1	8	8.6	2	8	1	8	8.6
2	Elazzazi-km-2	0.10	1	8	1	7	5.4	1	8	1	5	4.7
3	Elazzazi-km-7	0.10	2	8	1	8	8.6	2	8	1	8	8.6
4	Elharami-km-7	0.10	2	8	1	8	8.6	2	8	1	8	8.6
5	Elharami Branch	0.10	2	8	1	8	8.6	2	8	1	8	8.6
6	Toweher	0.10	2	8	1	8	8.6	2	8	1	8	8.6
7 (existing)	Elazzazi-end	0.15	2	8	1	8	13.0	2	8	1	8	13.0
8 (existing)	Elharami-km-1.35	0.15	2	8	1	8	13.0	2	8	1	8	13.0
						sum	74.5				sum	73.8
Southern Area												
9	Elmasid	0.15	2	8	2	8	17.3	2	8	2	8	17.3
						sum	17.3				sum	17.3

Note 1: With an assumption of 100 and 90 operating days in summer and winter seasons respectively.

Another factor in selecting pumps is the capacity of branch canals to accommodate the pumped drainage. Most branch canals in Abou Hammad are narrow and shallow with capacities of about 1 m^3/s. A sudden reduction of irrigation demand along a branch canal, for whatever reason, may result in flooding in the small channel. From a conservative point of view, the selection of smaller units with flexible unit numbers is more desirable.

<u>As seen in Tables 4-3, 4-4, and 4-5, the larger pump capacities of Scenarios #1 and #2 result in less than eight hours operation at several sites in the winter afternoon shift, while the smaller pump capacities of Scenario #3 maintain full-time operations at all sites except Site #2. Scenario #3 pumps less water but provides continuous pumping operations in either summer or winter seasons. Therefore, Scenario #3 is selected.</u>

<u>To achieve the drainage withdrawals targeted in Scenario #3, all reuse pump stations, especially the two existing stations, will have to closely follow the daily and seasonal operating schedules proposed. This will require further development of local water management capabilities.</u>

4.2.3 Reduced Winter Canal Supplies

In the winter season, drainage pumping can help reduce canal freshwater supplies. However, the reduction in freshwater will result in a smaller production of drainage. The question is by how much the canal supply should be reduced so that the intermediate reuse stations can continue operation at the reduced level of drainage generation. Table 4-6 shows the necessary amount of operating hours and pumped water when the canal supply is reduced by 10% and 20% in the *Northern Area*, using Scenario #3.

Table 4-6: Effect of Winter Canal Water Reduction in Northern Abou Hammad

		0% Canal Supply Reduction			*10% Canal Supply Reduction*			*20% Canal Supply Reduction*		
		Morning (hrs)	*Afternoon (hrs)*	*Pumped (1000 m^3/d)*	*Morning (hrs)*	*Afternoon (hrs)*	*Pumped (1000 m^3/d)*	*Morning (hrs)*	*Afternoon (hrs)*	*Pumped (1000 m^3/d)*
Northern Area										
1	*Lower Blad Elayed*	*8*	*8*	*8.6*	*8*	*8*	*8.6*	*5*	*5*	*5.2*
2	*Elazzazi-km-2*	*8*	*5*	*4.7*	*8*	*4*	*4.3*	*5*	*3*	*2.9*
3	*Elazzazi-km-7*	*8*	*8*	*8.6*	*8*	*8*	*8.6*	*8*	*8*	*8.6*
4	*Elharami-km-7*	*8*	*8*	*8.6*	*8*	*7*	*8.4*	*5*	*5*	*5.2*
5	*Elharami Branch*	*8*	*8*	*8.6*	*8*	*8*	*8.6*	*6*	*6*	*9.3*
6	*Toweher*	*8*	*8*	*8.6*	*8*	*8*	*8.6*	*5*	*7*	*6.4*
			Sum	*47.9*		*Sum*	*47.1*		*Sum*	*37.6*
						Reduced by	***2%***		*Reduced by*	***21%***

As seen in the table, at a 20% reduction of canal supplies, many reuse pump stations would be forced to operate less than eight hours during both operating shifts in the winter. There would be a 21% reduction of intermediately pumped water. This is not acceptable. At a 10% reduction of canal supplies, just one station, in addition to Site #2, would be forced to operate less than eight hours. The reduction of pumped water in the six stations would only be 2%. In other words, light fluctuation of canal supply won't change the yields of the reuse pump stations. The insensitive response of pumped drainage to a 10% reduction in canal supply indicates that Scenario #3 is a proper selection of pump facilities. A level of 10% is the upper limit of acceptable winter canal supply reduction in northern Abou Hammad. Meanwhile, canal reduction can only be as big as the drainage water going to the canal.

4.2.4 Summary

Table 4-7 below summarizes the quantities of drainage water to be intermediately pumped from the two areas of Abou Hammad according to Scenario #3.

Table 4-7: Summary of Intermediately Pumped Water

	Recorded Canal Inflow (mcm)	*Estimated Drainage Generation (mcm)*	*Monitored Drainage (mcm)*	*Estimated Unofficial Reuse (mcm)*	***Intermediate Pumping***		
					Volume (mcm)	*Ratio over Recorded Canal Inflow (%)*	*Ratio over Monitored Drainage (%)*
Northern Area							
Summer	*178.0*	*49.8*	*34.0*	*15.8*	*8.2*	*5%*	*24%*
Winter	*127.4*	*53.6*	*51.0*	*no reuse*	*6.6*	*5%*	*13%*
Southern Area							
Summer	*47.4*	*22.1*	*37.0*	*seepage effect*	*1.9*	*4%*	*5%*
Winter	*25.6*	*11.1*	*33.5*	*seepage effect*	*1.6*	*6%*	*5%*

The achievable intermediate reuse, in terms of its rate over canal water supply, will be 5% in the *Northern Area* and 4-6% in the *Southern Area*. In the Delta, the overall ratio of centralized drainage reuse over freshwater inflow is about 10% (36 bcm of Nile water, 4 bcm of shallow groundwater, and 4 bcm of official reuse). Compared to the centralized reuse, the 5% ratio of intermediate pumping seems to be low. However, there are two sides to this story.

On one side, centralized reuse stations pump water from main drains where the drainage flows of branch drains are collected in full, while intermediate pumping can only pump part of the flows in branch drains. Centralized pumping has an advantage in capturing capacity. This is why the main drain reuse approach was designed in the early years of the drainage reuse program, and why intermediate reuse cannot entirely replace centralized reuse.

On the other side, the 5% capture of intermediate pumps could not be harvested by the centralized pump stations due to the pollution in main drains. Note that since branch drain flows are rarely monitored while canal supplies are usually measured, the 5% intermediate reuse rate in respect to canal inflow can be a convenient estimate in assessing reuse potential.

4.3 Pumps and Stations

4.3.1 Mobile or Fixed Pumps?

Mobile pumps for intermediate reuse pumping were once thought desirable. However, fixed pump stations later become the preferred choice, for the following reasons:

- *Fixed reuse locations*. The drain water will be pumped from a fixed location in the drain to a fixed channel site of the branch canal. Certain engineering work, including outlet structure, concrete pipe, and stone pitching in both drains and canals, must be constructed. The reuse pumping is not mobile in nature.
- *Heavy operating duties.* As discussed above, the reuse pumps will operate in both summer and winter, with 200 operating days per year. Mobile pumps are not designed for such heavy operations. Frequent transporting of many pump units, including suction connections and delivery pipes, from pumping sites to the Irrigation District office or other storage houses would be expensive and unrealistic.
- *Expensive mobile pumps*. According to the available drain water at the seven selected locations, pump capacities are in the range of 0.10 - 0.15 m^3/s, as discussed in the previous section. Mobile pumps at this capacity level are not manufactured in Egypt and must be imported from other countries, which is not a favorable option.

As reflected in the socio-economic survey (Annex 4), farmers prefer fixed pumps in drainage reuse. Furthermore, to avoid the expensive investment of electric transformers, diesel engines will used in pump stations. Technical specifications of the two selected types of

Table 4-8: Pump Specifications

Specifications	**Unit of 0.15 m^3/s**	**Unit of 0.10 m^3/s**
Type of pump	*centrifugal*	*centrifugal*
Static head	*12 m*	*10 m*
Suction head	*4.0 m*	*4.5 m*
Pipe diameter	*8 inches*	*6 or 8 inches*
Revolutions	*1450 rvm*	*1450 rvm*
Diesel engine power	*43 HP (25 kW)*	*26 HP (15 kW)*
Chassis	*fixed with engine coupling*	*fixed with engine coupling*

Source: Egyptian pump market and manufactures

pumps are shown in Table 4-8.

4.3.2 Pump Station Design and Tender Document

The EPIQ drainage reuse task group prepared a detail design of the seven potential pump stations in Abou Hammad as part of the benchmark implementation. A project tender document for the development of the pump stations is included in Annex 1.

<u>4.3.3 Costs of Pumps and Stations</u>

The civil and mechanic costs for the pumps and station construction of Scenario #3 are given in Table 4-9 below. The total cost of the pumps and station construction will be LE 1.30 million, of which LE 0.74 million (57%) will be for the civil works, and LE 0.56 million (43%) for the pumps. These figures will be used for the economic and financial analysis in later chapter.

***Table 4-9: Capital Costs of Pumps and Station Construction** (according to Scenario #3)*

	Station Names	Pumped Water		Unit	Installed	Estimated Costs		
		Summer	Winter	Capacity	Units	**Civil**	**Mechanic**	**Total**
		m^3/day	m^3/day	m^3/sec		1,000 LE	1,000 LE	1,000 LE
1	Lower Belad Elayed	8.6	8.6	0.10	2	115	68	183
2	El-Azzazy Km 2.0	5.4	4.7	0.10	1	100	34	134
3	El-Azzazy Km 7.0	8.6	8.6	0.10	2	102	68	170
4	El-Haramy Km 7.0	8.6	8.6	0.10	2	103	68	171
5	El-Haramy Branch	8.6	8.6	0.10	2	100	68	168
6	Towehar	8.6	8.6	0.10	2	110	68	178
7	Elazzazi-end	13.0	13.0	0.15	2	(existing)		
8	Elharami-km-1.35	13.0	13.0	0.15	2	(existing)		
9	El-Masid	17.3	17.3	0.15	3	105	117	222
	Shared spare units [1]			0.10	2	(none)	68	68
	Sum	91.8	91.1			**737**	**559**	**1,296**

Note 1: Assumed that only the El Masid station has a stand-by unit installed, and all other stations share 2 spare units.

4.3.4 Desired Ownership and Operation Responsibility

There are two existing reuse pump stations in Abou Hammad, and five in Fakous. Most of them are not operating at the desired level. The experiences of these stations, particularly the negative lessons, provide good reference for planning new intermediate drainage reuse pump stations in Abou Hammad. Problems experienced at these stations include:

1. Inadequate drainage flows in the drains for pump operations. Pump operations are frequently stopped due to low drain water level or air bubbles in the pipelines. Rarely can operations continue beyond a period of two to three hours.

2. No demand on drainage water in the winter season given the sufficient canal freshwater supplies. Stations are idle and deserted for most of the year.

3. Insufficient budgets for regular engine maintenance, spare parts, and even the supply of diesel fuels. Pumps barely operate in the most severe canal shortage days during the summer months.

4. Weak institutional management. Unlike the centralized reuse stations, which are operated by formally organized mechanical engineers, intermediate reuse stations are currently under the responsibility of district irrigation engineers. Already working with limited manpower, district irrigation engineers might see the work as an extra burden on their regular work schedules, and become reluctant to care for the small reuse stations in distant locations unless a severe water shortage occurs.

In the design of Abou Hammad intermediate reuse stations, the first two problems are addressed by the technical proposals of drain weir construction, conservative selection of pump capacities and units, two shifts of continuous pump operating schedules, and reduction of winter canal supplies. The other two problems are of a financial and institutional nature. A key to resolving them is appropriate ownership and operation of these small reuse stations. Below are several foreseeable options regarding the ownership and operation responsibility of intermediate reuse facilities:

Opt 1. The GOE (MPWWR) pays all the costs (both capital and O&M costs), owns the properties, and expands district engineer staff to operate and maintain the intermediate reuse facilities.

Opt 2. Farmer organizations (such as the water user association) pay all the costs, own the properties, and operate and maintain the intermediate reuse facilities.

Opt 3. The GOE (MPWWR) pays the capital costs and holds the property ownership, while the farmer organizations pay the O&M costs, and operate and maintain the intermediate reuse facilities.

Opt 4. The GOE (MPWWR) pays all the costs, owns the properties, and contracts private companies to operate and maintain the intermediate reuse facilities.

Opt 5. Private companies pay all the costs, own the properties, and operate and maintain the intermediate reuse facilities by charging farmers.

Option #1 will add an extra burden to the overstaffed GOE body and continue the inefficient management of local drainage reuse. This is contrary to desirable institutional reform and should not be encouraged. Option #2, and even the more government-involved Option #3, overestimate farmers' financial situation and willingness for investment. Farmers will not accept these options at present, as revealed in Annex 4.

Private sector involvement in Egypt's water resources development is a promising idea. However, the sector is young and most likely does not have the economic capacity to initiate Abou Hammad intermediate reuse projects without governmental or international donors' financial support. Furthermore, without a reliable and attractive potential for profit, which would mainly be from the payments of either farmers or government, private sector participation remains unfeasible. As revealed in the socio-economic survey (annex 4), it would take time for Option #5 to become a real possibility. Option #4 is the preferable choice.

5. ECONOMIC ASSESSMENT

This chapter provides a summary of the economic analysis of the intermediate drainage reuse. A detailed report is found in Annex 2. The chapter begins with the identification of expected benefits from intermediate drainage reuse and then provides an identification of the project costs. Next, an economic analysis is presented including methodology, scenarios and alternatives, measures of project worth for intermediate drainage reuse sites and its aggregate, and a sensitivity analysis. A financial analysis for the farmers follows. Finally, the summary and conclusions are presented.

5.1 Expected Benefits

Benefits to intermediate drainage reuse include changes in net returns for some basic summer crops, the value of saved water in winter, and other benefits which were not quantified.

5.1.1 Changes in Net Returns for Basic Summer Crops

In the summer season, increases and stability in the water supply would result in an increase in yield for major summer crops. No water savings are anticipated. Expected increases in yields were obtained from informal interviews with farmers on the intermediate reuse sites in Abou-Hammad district (Table 5.1). Only cotton, rice, maize and vegetable yields were expected to increase. According to expert opinion, only 10% of any site would experience increasing yields. Crop budgets were obtained from Abou-Hammad Agri-district and Sharkia Agri-directorate for the 1997/98 Season, and changes in net returns by crop were determined (Table 5.1). Note that these returns are based on 1997/98 farm-gate prices.

In order to calculate expected net returns, actual cropping patterns for the proposed sites were obtained (see Annex 2, table 4 for detail). The cropping percentages were applied to the total area of the site. The resulting areas for each crop were multiplied by the expected change in net revenue to determine the expected increase in net revenue to farmers on that site (Table 5.2).

Table 5.1. Increases in yield and returns

Crop	Unit	Expected Yield Increase	Expected Yield Increase	Price (LE/unit)	Increase in Net Return
		Range	Mean		(LE)
Cotton	Kentar	1.0 - 1.5	1.25	500	63
Rice	Ton	0.5 - .75	0.63	730	46
Maize	Ardeb	3	3	75	23
Vegetables	%	30%	30%		42

5.1.2 Value of Saved Water in Winter

It was assumed that water deliveries to the canals would be reduced by the amount of the water pumped in the winter season be available for use in other location(s). A weighted average imputed value of about LE 0.10/m^3 was used to calculate the value of saved water (Mahdy, 1998). The quantity and value of saved water by site is found in Table 5.2. The quantity of water saved was obtained from the engineering team.

Table 5.2. Annual value of increases in yields and water saved

Drain Site	Area Served (fed)	Change in Net Revenue (LE)	Water Saved in Winter (M3)	Value of Water Saved (LE)
El Haramy Branch	700	10657	774000	77400
El Haraamy km 7	1760	44642	774000	77400
El Azzazy km 7	880	22230	774000	77400
El Azaazy km 2	544	16540	423000	42300
Lower Belad Elayed	1700	40365	774000	77400
Towehar	1400	51642	774000	77400
El Masid	1230	49837	1557000	155700
Total	8214	235913	5850000	585000

5.2 Project Costs

The capital costs include mechanical (pump) costs and civil works costs. Operation and maintenance cost includes fuel, oil, and labor wages. Capital, O& M and labor costs for the proposed intermediate reused seven pump stations at Abou Hammad were obtained from the EPIQ technical team and are presented in Table 5.3.

Table 5.3. Costs by Site (in LE)

Drain Sites	Capital Costs				Annual Costs		
Drain Sites	Civil	Pumps		Oper	Mtn	O&M	Labor
El Haramy Branch	100000	68000		32000	5040	37040	14400
El Haramy km 7	103000	68000		32000	5130	37130	14400
El Azzazy km 7	102000	68000		64000	5100	69100	14400
El Azzazy km 2	100000	34000		32000	4020	36020	14400
Lower Belad Elayed	115000	68000		32000	5490	37490	14400
Towehar	110000	68000		64000	5340	69340	14400
El Masid	105000	117000		64000	6660	70660	14400
Total	735000	491000		320000	36780	356780	100800

Pumps will have to be replaced once during the life of the civil works.

5.3 Economic Analysis of Pump Stations

5.3.1 Methodology and Assumptions

Three evaluation measures were computed for each of the seven intermediate reuse sites, and for the aggregation: the Benefit/Cost ratio (B/C ratio), Net Present Value (NPV) and Internal Rate of Return (IRR). The benefit/cost ratio compares the present worth of the gross benefit stream and the gross cost stream of a project and expresses their relation as a ratio. The simple decision rule is to accept the project if the B/C ratio is greater than one and to reject it if the ratio is less than one. The net present value is the difference between the present worth of the benefit stream and the present worth of the cost stream. The simple decision rule is to accept projects for which the NPV is positive (≥ 0). The internal rate of return is that rate of discount at which the present worth of the cost stream is equal to the present worth of the benefit stream. The simple decision rule is to choose or accept the project if its IRR is greater than the rate of interest.

The assumptions in this analysis (other than those discussed above) include:

- The discount rate is 12% (assumed equal to the opportunity cost of capital).
- All benefits and costs are expressed in 1997/98 prices.
- Economic life for civil works is 30 years and for the mechanical parts is 15 years.
- Benefits are achieved at the end of the year [discounted at $1/(1+r)^t$]
- Capital cost are paid at the beginning of the year [discounted at $1/(1+r)^{t-1}$]

Two scenarios were analyzed. The first assumed a value of water saved of LE 0.10 per m^3 and the second assumed a more conservative LE 0.08 per m^3. The latter value was taken from the Agricultural Sector Model for Egypt and other similar mathematical programming planning models.

5.3.2 Project Evaluation

Table 5.4 shows a summary of basic indicators for intermediate reuse project worth by site and aggregated for all sites. Results suggest the following conclusions:

- Given a value of LE 0.10/m^3 for saved water (Scenario 1):
  - (i) All sites except El-Azzazi Km 7.0 and El-Azzazi Km 2.0 have B/C ratios greater than 1, ranging between 1.19 for El-Haramy Branch site and 1.78 for El-Masid site. The corresponding IRR's ranges between 21% and 55%.
  - (ii) The aggregate B/C ratio is 1.32 and the IRR is 29.
  - (iii) For sites with B/C ratios greater than 1, NPV per feddan ranges between LE 125 for Towehar site and LE 591 for El-Masid site. For the aggregate, NPV per feddan is about LE 196.
- Given a more conservative value of saved water of LE 0.08/m^3 (Scenario 2):
  - (i) Three sites, El-Haramy Branch, El-Azzazi Km 7.0 and El-Azzazi Km 2.0, have B/C ratios less than 1. The other four sites have B/C ratios ranging between 1.06 for Towehar site to 1.51 for El-Masid site. The corresponding IRR's range between 16% and 40%.
  - (ii) The aggregate of all sites showed economic viability with a B/C ratio of 1.13 and an IRR of 19%
  - (iii) For sites with B/C ratios greater than 1, NPV per feddan ranges between LE 36 for Towehar site and LE387 for El-Masid site. For the aggregate, the NPV per feddan is about LE 81.

Table 5.4 : Summary of Basic Indicators for IDR Project Worth by Sites in Abou-Hammad District, Sharkia Governorate Under Alternative 0*

Site	Station Names	Served Area	Scenario 1 ** B/C ratio	NPV	LE/Fed	IRR	Scenario 2 *** B/C ratio	NPV	LE/Fed	IRR
1	Lower Belad Elayed	1700	1.55	335212	197.2	36%	1.34	210518	123.8	27%
2	El-Azzazi Km 2.0	544	0.87	-72387	-133.1	4%	0.74	-140534	-258.3	
3	El-Azzazi Km 7.0	880	0.94	-52493	-59.7	7%	0.79	-177187	-201.3	
4	El-Haramy Km 7.0	1760	1.64	384564	218.5	41%	1.43	259870	147.7	32%
5	El-Haramy Branch	700	1.19	114533	163.6	21%	0.98	-10161	-14.5	11%
6	Towehar	1400	1.2	174493	124.6	25%	1.06	49798	35.6	16%
7	El-Masid	1230	1.78	727089	591.1	55%	1.51	476251	387.2	40%
	AGGREGATE	8214	1.32	1611010	196.1	29%	1.13	668554	81.4	19%

* Productivity of summer crops will be improved in 10% of total served area .
** Saved water is valued at LE 0.10 /M3 (scenario 1).

*** Saved water is valued at LE 0.08 /M3 (scenario 2).

Source : Results of the analysis as shown in Annex 2

5.3.3 Sensitivity Analysis

Sensitivity analyses were performed to determine the effect of first, a 5% smaller increase in yield; second, a 5% reduction in the amount of saved water in addition to the 5% reduction in yield increase; and third a 5% increase in the operation cost of the project coupled with the two reductions in benefits. The general conclusion which can be drawn from these analyses is that for canals serving large areas (greater than 1,000 feddans) intermediate reuse is likely to be economically justified. For canals serving small areas (particularly those with less than 800 feddans), intermediate drainage reuse is probably not economically justifiable, and the smaller the area, the more unlikely is a positive economic evaluation.

5.4 Farmer Financial Analysis and Participation

A financial analysis based on returns to the farmer was performed to determine the capacity of farmers to participate in the construction, operation and maintenance of these intermediate pumping stations. The results are indicated in Table 5.5. In only two cases (El-Haramy Km 7.0 and Lower Belad Elayed) would increases in farmer income be sufficient to pay for even one half of the total cost of the project. In El-Haramy Branch, El-Azzazi Km 7.0, and El-Azzazi Km 2.0, benefits are less than one-quarter of the full project costs.

Table 5.5. Financial analysis by site

Drain Site	Increased Annual Net Revenue	Annualized Capital Cost (12%)	Annual O & M plus Labor Cost
El Haramy Branch	10,657	22,398	51,440
El Haramy km 7	44,642	22,770	51,530
El Azzazy km 7	22,230	22,646	83,500
El Azzazy km 2	16,540	17,406	50,420
Lower Belad Elayed	40,365	24,261	51,890
Towehar	51,642	23,640	83,740
El Masid	49,837	30,213	85,060

It is more likely, however, that farmers would be expected to participate in only the operation and maintenance of the project (including labor costs). The values in Table 5.5 indicate that returns to farmers are less than the O&M costs of the project. In the two most favorable cases, the El Haramy km 7 and the Lower Belad Elayed, farmers could pay about 90% of O&M costs. These canals serve the largest areas. However, in the three least beneficial cases (El Haramy Branch, El Azaazy km 2 and km 7), farmer returns would be less than one-third of the O&M costs. In general, the smaller the area served, the smaller the net return gain compared to costs.

It should also be noted that only the farmers in the tails of the canals will benefit from increased returns. Thus only they would be willing to participate financially in the project, and equity suggests that only they should be required to support development costs. The assessment of cost sharing would be a relatively difficult administrative task.

One goal of the intermediate reuse project is the saving of water and diversion of the saved water to new developments in order to accommodate increasing population pressure. As such, the project has social benefits over and above the increase in returns to farmers. The GOE should expect to pay most of the costs of Intermediate Reuse, with only minor participation of farmers.

5.5 Economic Assessment Conclusions and Recommendations

Results of the economic analysis under Scenario 1(LE 0.10/m^3) showed that:

- All sites except El-Azzazi Km 7.0 and El-Azzazi Km 2.0 are economically viable with B/C ratios ranging between 1.19 and 1.78. The corresponding IRR'S range between 21% and 55%.
- The aggregate B/C ratio IS 1.32 and THE IRR about 29%.
- For sites with B/C ratio greater than 1, NPV per feddan ranges between LE 125 and LE 591. For aggregate, NPV per feddan is about LE 196.

A reduction in the value of water saved to LE 0.08/m^3 resulted in:

- One additional site (El-Haramy Branch) having a B/C ratio less than 1.
- Decreased B/C ratios and corresponding IRR's for the remaining four sites. B/C ratios range between 1.06 and 1.51 and corresponding IRR's range between 16% and 40%. %. NPV's per feddan range between LE 36 and LE 387. The aggregate B/C ratio was 1.13, the IRR was about 14%, and the NPV per feddan was about LE 81.

Five percent decreases in yield improvement and saved water coupled with a 5% increase in operating costs resulted in one more site (Toweher) with a B/C ratio less than 1. In addition, the economic feasibility of intermediate reuse sites is most sensitive to increases in cost and reductions in the quantity of saved water.

Farmers financial analysis showed that annual revenues to farmers insufficient to pay full project cost or O & M costs. Because the project has social benefits over and above the direct increase in returns to farmers, the GOE should expect to pay most of the costs of Intermediate Reuse, with only minor participation of farmers.

6. ENVIROMENTAL ASSESSMENT

This chapter assesses the physical, social and ecological impacts of the adoption of intermediate reuse in Abou Hammad. The Environmental Impact Assessment (EIA) is prepared according to the standard format of the Egyptian environmental affairs agency and in conformity with the guidelines of the World Bank. The background behind adopting the intermediate system is explained. and the current status of the physical and biological components of the project is documented. Socio-economic data describing the current status of the project area are also given for future comparison and implementation of mitigation measures for negative impacts.

6.1 Methodology

Baseline data from studies carried out by previous MPWWR projects were used as background information for the assessment of the current status of the project area. A matrix system is used to describe the assessment of important factors in the evaluation of the different projects' impacts.

Some items were changed and others were added to make the matrix system suitable for requirements of the project. The eight main environmental topic areas and 44 sub-areas were selected for the assessment. Mitigation measures are given for each negative impact. A matrix is prepared as a summary for all the impacts.

6.2 Results of the Impacts Assessment

The attached matrix (Table 6.1) shows 44 impacts as decided upon by the scoping process. The main areas of concern are impacts on hydrology changes, pollution sources, soil as impacted by the project, sediments in the system, ecological changes in the area of the project, socio-economic changes impacted by the system, health of the population impacted by the system, and any expected imbalances. The evaluation of the expected different impacts is given for each of the scoped at impact (Annex 3 section 6).

6.3 Mitigation Measures

Use of canal water for drinking, using compact water treatment plants, mandates a certain quality of intake water. Deterioration of canal water, due to the pumping of polluted drain water and other previously mentioned sources of pollution, can reduce the quality of the treated drinking water. This problem can be overcome by adopting the intermediate reuse system in conjunction with the diversion of the collected and treated domestic and industrial wastes as mandated by the law 48. Reusing the treated waste effluents in agriculture can save more water for irrigation withdrawn from canals.

Continuous flow in the canals and unlined mesqas may encourage weed growth due to the absence of dry periods. This can be controlled by manual mesqa cleaning, which the farmers are accustomed to performing cooperatively. Chemical weed control applications should be avoided in order to reduce toxic accumulation in agriculture lands. Which could lead to reduced crop productivity in the future.

Lowering the water level can have an impact on fish productivity in drains. Fish caught in drains are usually few and not recommended for human consumption. On the other hand, augmenting water in the canals can enhance their fish catch for better quality fish.

Concentration of heavy metals and toxic organic chemicals is high in drain water impacted by different sources of pollution with low ratios of dilution. This in turn will impact the canal water receiving the drain water. Elimination of sources of pollution is vital for the success of the drainage water reuse system.

Table (6.1) Matrix for IDR Environmental Impact Assessment

	For each environmental effect place a cross(x) in one of the columns	Possitive Impact Very Likely	Possitive Impact Possible	No Impact Likely	Negative Impact Possible	Negative Impact Very likely	No judgement Possible at present	Comments
		A	B	C	D	E	F	
Hydrology	1-1 Low flow regime	x						
	1-2 Operation of dams		x					
	1-3 Fall of water table	x						
	1-4 Water availability	x						
Pollution	2-1 Solute dispersion	x						
	2-2 Toxic substances				x			
	2-3 Organic pollution	x						
	2-4 Gas emissions	x						
Soils	3-1 Soil salinity				x			
	3-2 Soil properties				x			
	3-3 Saline Groundwater				x			
	3-4 Soil Drainage				x			
	3-5 Saline intrusion	x						
Sediments	4-1 Local erosion	x						
	4-2 Hinterland effect						x	
	4-3 Channel regime		x					
	4-4 Sedimentation				x			
	4-5 Estuary erosion				x			
Ecology	5-1 Project lands				x			
	5-2 Canals and Drains				x			
	5-3 Surrounding area		x					
	5-4 Shores of Lake Manzala				x			
Socio-economic	6-1 Population change				x			
	6-2 Income & amenity	x						
	6-3 Human migration		x					
	6-4 Resettlement		x					
	6-5 Women's role		x					
	6-6 Minority groups						x	
	6-7 Sites of value						x	
	6-8 Regional effects	x						
	6-9 User involvement	x						
Health	7-1 Water & Sanitation	x						
	7-2 Habitation		x					
	7-3 Health Services	x						
	7-4 Nutrition		x					
	7-5 Relocation effect		x					
	7-6 Disease ecology						x	
	7-7 Disease hosts						x	
	7-8 Disease control		x					
	7-9 Other hazards		x					
Imbalances	8-1 Pests & weeds		x					
	8-2 Animal diseases						x	
	8-3 Aquatic weeds					x		
	8-4 Structural Damage		x					
	Number of crosses							Total 44

Increasing the amount of water available to middle and tail farmers who generally apply more fertilizers and pesticides to their land, can lead to higher levels of groundwater contamination.. Increased nitrates and/or ammonia can lead to health problems such as fatal blue babies disease, spontaneous abortion in females, cancer colon in both males and females, and child anomalies. Tail end soils are usually sandy, allowing for easy migration of chemicals dissolved in the water. Optimization of agrochemical use should be adopted in those areas. as well as all agriculture areas in Egypt, to reduce agriculture cost, agrochemical residues in the crops and accumulated soil toxicity in the long run.

6.4 Environmental Assessment Conclusions and Recommendations

An intermediate drainage water reuse system can be a successful mechanism for satisfying the increasing demand for irrigation water while securing reasonable rates of dilution for drainage water salinity. All anticipated side effects from the wide use of the system are controllable.

Based on community meeting about the project, farmers are willing to adopt the system in order to achieve water equity and reduce their reliance on privately - owned pumps. Unofficial reuse has lead to uneven access to irrigation water in addition to soil deterioration as a result of excessive irrigation. Also the use of farmers' pump sets has impacted the stability of the banks in some secondary drains. In addition, tail farmers were practicing the use of higher salinity water.

The role of rural populations in reducing pollution to drains and canals should be stressed. Minimization of wastes by rural communities to improve the irrigation water quality is key to both improving the quality of crops and to achieving project sustainability. The important role of women in this respect should be strengthened through awareness and educational programs conducted at the community level. Mass media and audio-visual communications are necessary given their high illiteracy rates.

Environmental management of the project mandates the conduct of environmental auditing by a group of experts coordinated by a senior environmental expert. Mitigation measures for the possible negative impacts of the system are known and their adoption has to be insured through environmental auditing. Audit results have to be well documented as one of the legal requirements of the Environmental Law.

There is a need for environmental management training for the project team to integrate the environmental dimension while planning, implementing and evaluating the project.

Environmental awareness and training for rural community leaders (men and women) is a vital tool for the successful conduct of the project carried out by farmers.

Monitoring activities are essential to detecting any unforeseen negative impacts. Monitoring parameters are given in Annex III, section 9 in order to help the adoption of mitigation measures in due time and to insure project sustainability.

7. SOCIO-ECONOMIC ASSESSMENT

This chapter provides a summary of the social aspect of intermediate drainage reuse (A detailed report is given in Annex 4). The social assessment aims at describing and analyzing farmers' and irrigation engineers' attitudes towards intermediate drainage reuse in irrigation and their views of its impact on health, soil and crop production. Furthermore, it attempts to determine the extent and causes of farmers' reliance on intermediate reuse in the irrigation of their crops when there is a shortage of water, especially at tail ends.

7.1 Survey Data

Two questionnaires were designed - one for the farmers and one for the engineers. The two questionnaires were very similar in scope except for questions related to specific characteristics of the farmer respondents, (e.g. age, area of land holding, classification of land, village name, and educational level). In addition, the engineers' questionnaire included a technical question related to the kind of structure and the manner in which a mixing station should be constructed. One important difference is noted with respect to the wording of the questions: the farmers' questions focus on their actual behavior, whereas the engineers questions focus on what they perceive the farmers are doing. Both questionnaires included twenty questions that dealt with: 1) the use of intermediate drain water and its impact on soil and crops, 2) the impact of drainage water on public health and the environment of the domicile (e.g.. access to tap water, sewage, waste elimination, etc.), 3) attitudes towards participation in the cost of operation and maintenance as well as the preferred modes of operating such mixing stations, and 4) cropping patterns.

A sample of 33 farmers was selected from several villages in the district of Abu Hammad. The farmers use different irrigation canals and different drains covering the entire district. This, however, is not meant to indicate representativeness. All respondents either owned or rented land have agriculture as main occupation. In addition, twelve irrigation and drainage engineers were interviewed. They varied considerably in rank and in the number of years of work experience. They belonged to different administrative levels: three are working in Abu Hammad district, one in Al-Salhya, five in the central governorate office in Zagazig, two in the ministry headquarters in Cairo, and one with USAID. The farmers' data were collected on February 10, 1999, and the data from the engineers on the following day.[1]

[1] In addition, a group discussion was held on March 24,1999 in Ezbat Hanna Al-Sughra, a small hamlet 3 km to the West of Abu Hammad just off the road to Zaqaziq, eight farmes attended. It lasted for about 2 hours. For

7.2 Related Problems and Issues

7.2.1 Farmer/Cultivator Characteristics

The farmers' questionnaire included a limited number of questions related to their socio-economic profile and specific questions related to age, education, land - holding classification, land location and crop structure.[2] The youngest respondent was 29 years old while the oldest was 67. The average age reported was 52 years.

Only 42% of the sample responded to the question regarding educational attainment. (Of this, 42.9% (six persons) were illiterate, and the remaining 57.1% (8 persons) indicated that they could read and write. The former of the two figures comes close to the national level of rural male illiteracy, which was 46.9% in 1986 (cf. CAPMAS, 1991).

Regarding reported land – holding, all 33 farmers in the sample were outright owners or rented, with a total of 93.25 feddans. This amounts to an average holding of a little less than three feddans (2 feddans and 20 qirrats). Only 3 persons reported renting land. The smallest reported land area owned was about half a feddan, and the largest was six feddans. This indicates a highly heterogeneous sample of land owners, some of whom have to combine work on their own land with work as wage laborers, or other sources of income, in order to maintain their livelihood.

None of the farmers owned or rented in land at the head of the canals. 41.9% reported holdings in the middle of a canal and 58.1% had lands located at the tails of the canals, from which they were suppose to irrigate.

---

about another 2 hours during that day, the author drove along Al-Sheik Hammed canal and talked to another 4 peasants individually to collect necessary information for this report.

[2] Gender issues related to intermediate drainage reuse were addressed through a separate focus group workshop with village women stakeholders.

7.2.2 Farmers' and Engineers' Cropping Patterns and Productivity

One of the main characteristics of the cultivation behavior of farmers in the sample is the intense exploitation of the land at their disposal. This is a distinctive feature of Egyptian agriculture in general and small cultivators in particular. According to farmers surveyed there are no significant seasonal variations in the proportion of land they exploit. During the winter, 87.9% of the total area are cultivated with traditional crops and vegetables, while the corresponding proportion during the summer season is about 85.8%. Permanent orchards are cultivated on 1.3% of the land.

There is a greater divergence of views on crop patterns between estimates of the farmers and those of the engineers on the one hand, and between each of the two groups and the actual figures of crop pattern of the MALR administration on the other hand.

7.2.3 Domestic Environment and Drainage Practices

Rural men and women come into contact with drains on a daily basis and in different ways. The drain is used as a repository for wastewater and solid wastes and sewage, as well as a source of supplemental irrigation water. The physical infrastructure in rural Egypt, Abu Hommad included, is very conducive to domestic use and abuse of drains. While 100% of the farmers surveyed stated that their houses are connected to drinking water supply, only 30.3% of the sample said that their homes are connected to a sewage disposal system.[3] Of those engineers who responded to the question of whether farmers' houses are connected to a sewage system, 100% replied in the negative. Thus, the majority of farmers in our sample (80% of respondents) have septic tanks sewage disposal (which are emptied every three months 25% or after six or more months (75%).[4]

[3] It is likely that those who responded in this way misunderstood what the term “sewer” means. During a crosscheck visit following the survey, many people said they thought it referred specifically to a septic tank system. In each of the questionnaires the surveyor filled, the question "Is your house connected to a sewer?" was left blank, and “The tank that is emptied every three months" was written. Very few villages in Egypt are connected to a sewage system.

[4] A recent study of septic tank bailers in two Upper Egyptian Governorates shows that septic tanks are undermining the structural foundations of houses in the countryside and that some of the Delta villages are currently floating atop marshy land. Furthermore, sewage is intruding on ground water.

7.2.4 Gender Issues

Rural women relate to the drains in a different manner. In a follow-up meeting to the survey in April 1999, 30 village women respondents indicated that they have previously made arrangements to have waste water collected from their homes for a fee, but that in the final analysis it all ends up being dumped into the drains or canals. Because of the lack of solid waste collection in the villages, it is dumped on the banks of the waterways. The majority of women recognize this as having a direct effect on community health and hygiene. Further, they expressed a readiness and keenness to participate in decision-making and implementation of activities which will improve this situation. Regarding the question of whether women in the area realize the impact of intermediate drainage water reuse on land productivity, 75% of the participants were unaware of the benefits or the detriments. Regarding effect on water quality of direct discharge of domestic sewage and solid waste accumulation, all participants expressed their awareness of the pollution generated by both domestic wastewater and solid waste accumulation. With respect to solid waste management, the women suggested that the local leaders should organize a tractor to collect their solid wastes once every week to prevent them from accumulating garbage on the banks of waterways (i.e. both drains and irrigation canals). A few women indicated garbage is also used as a source of fuel in the ovens, and in such cases there is only minor disposal.

7.2.5 Farmers' Perceptions of Water Shortage

When farmers speak of water shortage there is some degree of variance among their perceptions. Broadly there are two definitions of water shortage, related to spatial and temporal perceptions. In some instances, it is referred to as having to lift water by any device, be it a pump or water wheel or any other means, which entails high costs or longer time devoted to irrigation. In other instances, the farmers referred to the irregularity in rotation and/or the low level of water in the canals, i.e. the quantities of discharged water are not sufficient. A third perception of water shortage is determined by the location of the land on the mesqa (head, middle or tail reach) which leads to shortages due to inequity. Situations of inequity appear to be determined not only by the physical location of the field on the mesqa, but also by social factors. Villagers speak of the ability of those persons with authority or connections to authority and their ability to influence the duration of rotations. For some respondents, water shortage means that water is not available at all during the rotation period assigned to their village. In addition, they tie shortages to seasons and hence to certain levels of water requirements for each crop, especially rice. In such cases, farmers link it to the various stages during the cultivation cycle. Thus, in rice cultivation, for example, a distinction is drawn between the "Taghriq", i.e. the flooding of the field for the first time which requires pumping roughly six hours per feddan, and the "Tamliah", refilling the paddies to compensate for water consumed by the crop or through evaporation.

7.3 Effects of Intermediate Reuse

Concern about the effects of intermediate drainage water reuse was addressed in this survey by looking at three major elements:

- impact on crop yield,
- impact on soil, and
- impact on public health issues.

With regard to impact on crop yields, the majority of farmers, i.e. 93.9%, believe that the reuse of drainage water will have a positive impact on yields at canal tail ends, while 75.8% think that drainage irrigation would have a beneficial impact on crop yields generally. 15.2% of the respondents felt that it makes no difference. Of those who think that drainage irrigation increases crop yields, 34.4% stated that it generally leads to a 1-5% increase in production. An equal percentage of farmers indicated that the increase would exceed 5%. Only 6.3% of the farmers believe that using drainage water will have a negative impact and lead to a decrease in crop production by 1-5%.

Regarding impact of drainage water on soils, both sets of respondents are in basic agreement: 48.4% of farmers and 45.5% of engineers stated that it would adversely affect the soil. 32.3% of farmers and 27.3% of engineers were unsure whether there would be a negative impact. A third of the farmers indicated that there could be increased soil salinity, particularly if drainage water used for irrigation is brackish. Most others stated in general terms that they would expect to see a decline in soil quality as a result. Only one farmer said that it would reduce dependence on fertilizers.

There are considerable differences between the farmers and engineers in terms of their awareness of the impact of drainage irrigation on general community hygiene. Only 27.3% of the farmers stated that drainage water adversely affects general hygiene, as compared to 58.3% of the engineers. Meanwhile, 57.6% of the farmers believe it does not have an impact, compared with 8.3% of the engineers. It should be noted that in post-survey crosschecking, most farmers appeared to be very much concerned with the impact of the drains on public health.[5]

7.4 Construction, Operation, and Maintenance of Pump Stations

Regarding construction, operation and maintenance of pumping stations several views came to the fore. The first of these relates to the technical complexity, and there was general agreement that engineers are best positioned to determine their specifications. The majority of the responding engineers indicated that they prefer to construct a stationary concrete pumping station (83.3%). The reasons given by some engineers relate to durability over time, while others indicate it would prevent disputes among farmers, particularly compared to mobile stations. Relative ease of operation and maintenance was another reason given by the engineers for the preference of the fixed type of construction.

With respect to farmers' participation in the construction and recurring operating costs of the reuse station, a majority of both engineers and farmers indicated that farmers could not afford to finance the entire construction (80% and 71% respectively). Some engineers (20%), however, believed that some farmers could afford to contribute to construction cost. Nearly a third of the farmers (29%) stated that they would be ready to contribute with other users to the cost of construction.

The engineers are much less clear on the issue of the cost of operation and maintenance of the station. They are evenly split between those who believe that farmers can participate and those who think they cannot. Among farmers, the response is similar to those with respect to station construction, i.e. 25.4% are willing to share the cost, while 74.6% are not sure. However, during the focus group workshop, most of the attending farmers stated that the reluctance on their part stemmed from their lack of technical capability, and that they would be interested in taking on O&M responsibilities, if they received training and the skills necessary to operate the system efficiently.

Regarding the responsibility for operating the reuse pumping stations, 71.4% of the farmers indicated they would like the local councils to take this on. Only 33.3% believed it should be handed over to users' associations, and just 6.7% preferred private companies. Again, it should be noted that farmers attending the focus group workshop did not preclude the

[5] On a farmer said "the drain cuts across the heart of the village, the children are playing in it. This is going to harm their health". Another farmer was more dramatic: "Water related diseases are causing a lot of problems, Bilharzia, kidney failure, and virus C. I always go to get burial permits, everytime some urinary system disease is present in our water supply". (cf. Interviews by Dr. M. Mohieddin, March 1999).

possibility of taking on this responsibility at a later point in time, i.e. after attaining an adequate level of technical capability as well as confidence in their users' associations to effectively handle the work.

83.3% of the engineers believed that users' associations are in the best position to run the stations. They also differed with the farmers in that only 25% accepted the possibility of the local councils running the stations. Similarly, 25% accepted the option of entrusting the private sector to operate the station.

7.5 Social Assessment Conclusions and Recommendations

The analysis of this socio-economic survey indicates that the majority of farmers are essentially oriented toward subsistence, with minor marketable surplus commodity production. It further shows that water shortage is a major concern for them. In their view, water shortage can assume different forms temporal and spatial, and relative as well as absolute. In response to these shortages, farmers depend heavily on drain water to compensate. Both engineers and farmers tended to over - estimate the reliance of farmers on drainage water, with each group of respondents having its own reasons.

Both farmers and engineers agree, to varying degrees that the application of drainage water for irrigation will impact on soils, health, and crop productivity. Most believe that it will increase soil salinity, but will also increase production. A majority of the farmers are either not sure or do not know about potential the exact impact of drainage water on health. To the contrary, a majority of engineers stated that drainage water would have a negative impact on community health and personal hygiene. Significantly, neither group was aware of the potential impact of drainage water on the spread of specific vector-borne diseases.

At this stage, farmers are generally reluctant to fund construction of the mixing stations, and engineers believe that the majority of farmers cannot afford this burden. A larger proportion of the engineers feel that farmers would be able and willing to contribute to the cost of operation and maintenance of such stations. Interestingly, farmers are less enthusiastic about this. There is also some difference of opinion between the two groups with regard to the best qualified body for the running of the station at this current juncture: whereas farmers prefer the local councils, engineers believe the WUA's are best positioned.

8. CONCLUSIONS

Agricultural drainage reuse is, and will continue to be, an important source of the irrigation in the Delta. However, the current main drain reuse system is threatened by increasing contamination from municipal and industrial wastewater discharge, and shows a stagnant or even a shrinking trend in reuse operations. This calls for a policy change to shift reuse operations from main drains to branch drains, or the intermediate use of drainage water. Such a shift is a natural step in the Delta region's drainage reuse management. Intermediate drainage reuse helps capture good quality branch drain water, overcoming branch canal tail end water shortage, replacing uncontrollable unofficial drainage pumping, and promoting farmer involvement and organization in local water management. Liked or not, intermediate reuse will be a fast-growing reuse pattern in conjunction with the existing main drain reuse.

Bahr Bagar Drain Basin

The southern part of Bahr Bagar (Qalubyia and Belbeise drains) starts with a large amount of sewage from the East Bank of Cairo, effectively making Bahr Bagar more an open sewer than an agricultural drain. The operation of Gabal El Asfar and Burka wastewater treatment plants has helped clean the Belbeise drain since last October, but the treatment of the industrial wastewater of Shoubra El Kheima needs more time. The cleaning of Qalubyia drain, and consequently the entire Bahr Bagar, will take a while.

It is widely agreed that treated sewage can be reused in irrigating certain, but not all, agricultural crops. Therefore, the treatment does not create general irrigation reuse potential in Bahr Bagar, and the use of the effluents from the east bank of Cairo depends on the availability of the new lands for special crops suitable for wastewater irrigation.

The northern Bahr Bagar collects a mighty flow of drainage from the newly reclaimed lands along the Salam Canal. However, the drainage is very saline, and reuse of the water is not envisioned at the present time.

The middle part of the Bahr Bagar basin is a traditional agricultural area. The area generates good quality irrigation drainage and provides a favorable condition for the development of intermediate drainage reuse. The middle part is the only part of the entire Bahr Bagar basin in which reuse can be developed through intermediate pumping on branch drains.

Intermediate Drainage Reuse in Abou Hammad

Chapters 4 and 5 conclude that Abou Hammad has a promising future of intermediate drainage reuse. Table 8-1 below summarizes the needed pump equipment, the operation hours, and the amount of drainage to be seasonally pumped in Abou Hammad. One of the seven selected sites, Elazzazi-km-2, was dropped for environmental and economic considerations. There will be five reuse stations in northern Abou Hammad and one station in southern Abou Hammad, in addition to the two existing reuse stations. For the summer season, the pumped drainage will be 7.6 mcm in the north and 1.9 mcm in the south. For the winter season, the pumped water will be 6.22 mcm in the north and 1.56 mcm in the south.

Table 8-1: Operating Hours and Seasonal Pumped Waters

	Pump Sites	Unit capacity m^3/s	Installed units	Daily operation unit-hours	Summer (110 days) pumped water mcm / season	Winter (90 days) pumped water mcm / season
Northern Area						
1	Lower Belad Elayed	0.10	2	24	0.95	0.78
2	El-Azzazy Km 7.0	0.10	2	24	0.95	0.78
3	El-Haramy Km 7.0	0.10	2	24	0.95	0.78
4	El-Haramy Branch	0.10	2	24	0.95	0.78
5	Towehar	0.10	2	24	0.95	0.78
6	Elazzazi-end	0.15	2	24	1.43	1.17
7	Elharami-km-1.35	0.15	2	24	1.43	1.17
				Northern sum	**7.60**	**6.22**
Southern Area						
8	Elmasid	0.15	3	32	1.90	1.56
				Southern sum	**1.90**	**1.56**

To achieve the intermediate reuse targets, the proposed drain weirs must be constructed to establish nighttime drainage storage, and the designed pump operation schedules must be closely followed. Pumps will operate 110 days in the summer season and 90 days in the winter season. Every station except Elmasid will have two units operating in the morning and one unit operating in the afternoon (Elmasid will have two units operating in both shifts). Clearly, the restricted operation schedules will improve the capability of local water management.

Summer drainage pumping is designed to overcome canal end shortage. Intermediate reuse will largely, if not fully, replace Abou Hammad's unofficial drainage pumping. Winter drainage pumping is designed to save 5% canal delivery. In practice, this 5% canal reduction must be implemented not only for water savings but also for the on-schedule operation of intermediate reuse pumps in the winter season.

Table 8-2 presents the capital costs of Abou Hammad intermediate reuse development. One interesting note is that the capital cost of LE 1.16 million almost equals the cost of digging one groundwater well in Farafa Oasis; however, while the lands the intermediately pumped drainage can irrigate are incomparably larger than what the well water could cover. Intermediate drainage reuse is economically attractive, compared to many other water conservation or augmentation options in the case of Egypt.

Table 8-2: Capital Costs of Pump Stations

	Station Names	Type of Pumps m^3/sec	Needed Units	Capital Costs		
				Civil 1,000 LE	Pumps 1,000 LE	Sum 1,000 LE
1	Lower Belad Elayed	0.10	2	115	68	183
2	El-Azzazy Km 7.0	0.10	2	102	68	170
3	El-Haramy Km 7.0	0.10	2	103	68	171
4	El-Haramy Branch	0.10	2	100	68	168
5	Towehar	0.10	2	110	68	178
6	Elazzazi-end	0.15	-	-	-	-
7	Elharami-km-1.35	0.15	-	-	-	-
8	El-Masid	0.15	3	105	117	222
	Shared Spare Units	0.10	2	-	68	68
			Total	**637**	**525**	**1,162**

Chapter 5 concludes, from the farmer financial analysis, that the Egyptian government should be responsible for the major part of the capital and O&M costs of intermediate reuse development and operation. Furthermore, only the farmers who directly receive pumped drainage would be willing to share part of the pump station O&M costs. The two socio-economic surveys reported the same reactions from farmers, as described in Chapter 7. This is not encouraging but may remain true given present overall pricing realities. Wastewater treatment and other water conservation options have similar cost sharing problems.

Environmentally, the widespread agricultural land use and the consequent good quality of drain water in Abou Hammad will sustain the reuse of drainage in the area. In any event, branch drain reuse in Abou Hammad is better than the use of Bahr Bagar main drain water.

The majority of the farmers surveyed favors intermediate drainage reuse, as reported in Chapter 7. Farmers also prefer government ownership of pump facilities and responsibility for operations. Chapter 4 suggests a compromised solution, i.e., the government pays the cost, owns the properties, but contracts private companies to operate and maintain the pump facilities.

9. REFERENCES

Abu Zeid, M., “Future Challenges regarding Egypt’s Water Resources Policies,“ A keynote speech to the workshop of Drainage Water Irrigation Project, Alexandria, October 5-7, 1997.

EPIQ Water Policy Team (Z. Zhu, I. Elassiouti, F. Khattab, and A. Ragab), “National Policy for Drainage Water Reuse,“ Benchmark Report #8, APRP Water Policy Reform Activity, June 1998.

Drainage Research Institute, “A Water Quality Baseline for Bahr Bagar Drain and Lake Manzala as Affected by Wastewater,“ Report submitted to Department for International Development, United Kingdom, December 1997.

Zeinab Nabih Monir, “A Study of the Sewage in Gabal El Asfar Area,“ Cairo Wastewater Organization, January 1998.

Fatma El Gohary, “Comparative Environmental Risks in Cairo – Water Pollution Problems,” a circulated paper, December 1997.

Elassiouti, I., “Water Quality Monitoring in Egypt”, a report presented to the Advisory Panel on Land Drainage and Drainage Related Water Management, 1995.

Drainage Research Institute, “Reuse Monitoring Program – Yearbook 1993/94,“ August 1995.

Sir Mott MacDonald & Partners Ltd., “Rehabilitation and Improvement of Water Delivery System in Old Lands (Project Nr. EGY/85/012), Annex F: Feasibility Report – Saidiya Command Area,” Ministry of Public Works and Water Resources, May 1988.

Sir Mott MacDonald & Partners Ltd., “Nile Water Resources Management,” Irrigation Sector, Ministry of Public Works and Water Resources, 1991.

Elwan Hussein S., “Inflow-outflow Method for Seepage Estimation from Ismalia Canal,” a report published by the Hydraulics & Sediment Research Institute, Ministry of Irrigation, Water Research Center, February 1987.

Zhu Z, Laila Abed, and Nagy G. Yakoub, “Revised Nile River Water Balance, Years 1987-1993,” Strategic Research Program working paper series No. 34-5, National Water Research Center, Cairo, Egypt, August 1995.